NASA Technical Memorandum TM 102148

KSC Ice/Frost/Debris Assessment For Space Shuttle Mission STS-29R

April 1989

National Aeronautics and Space Administration

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KSC ICE/FROST/DEBRIS ASSESSMENT
FOR
SPACE SHUTTLE MISSION
STS-29R
MARCH 13, 1989

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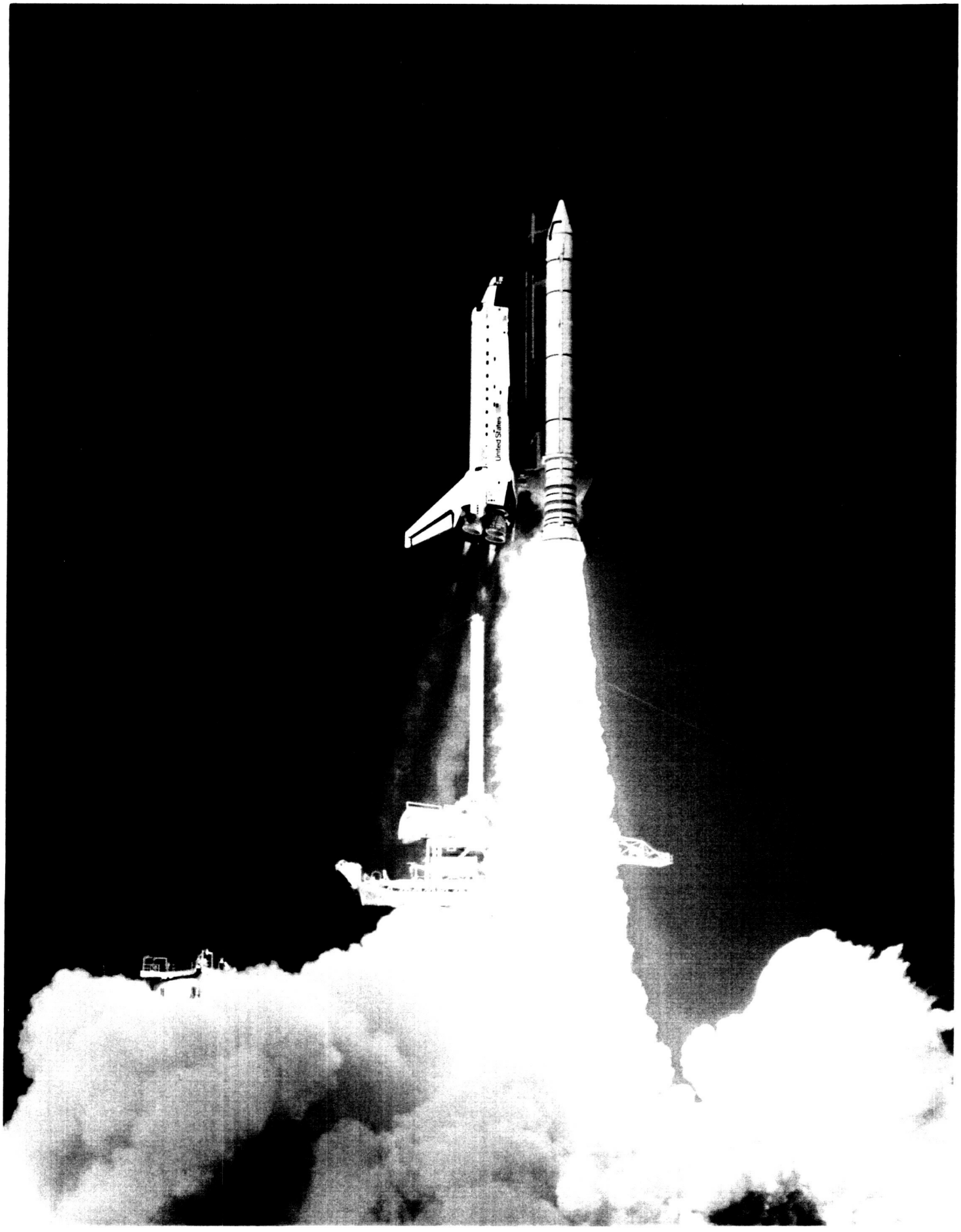
FORWARD

The Debris Team is continuing its effort to develop and implement measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine processing and operations.



LAUNCH OF STS-29R ON MARCH 13, 1989

1.0 Summary

Ice/Frost/Debris Team activities for Mission STS-29R began with the pre-launch debris inspection of the launch pad and Shuttle vehicle on 12 March 1989. No major anomalies were observed on OV-103 Discovery, BIO-31, or ET-36. The External Tank hydrogen fire detection system (butcher paper) was ripped or missing at 5 locations. This occurred during high winds and was documented on a PR. Minor facility discrepancies, which included loose bolts on SSME sound suppression water lines, loose MLP deck bolts, loose electrical access covers, and small quantities of trash on the MLP deck and around the holddown posts, were corrected prior to cryo-loading the vehicle.

ET-36 was cryo-loaded for flight beginning on 12 March 1989. Infrared measuring devices recorded average temperatures (F) of 51 deg on the LO2 tank, 58 deg on the intertank, 48 deg on the LH2 tank, 58.5 deg on the SRB cases, 68.5 deg on the SRB field joints, and 62 degrees on the Orbiter surfaces.

Less than typical accumulations of ice/frost were present in the LO2 feedline bellows and support brackets and on the LO2 ET/ORB umbilical. Acreage frost had formed on the LH2 tank +Y side. The frost, which was less than 1/16-inch thick and acceptable per the nomographs/NSTS-08303 criteria, was later diminished by the sun and wind, and virtually gone by launch.

Typical amounts of ice were present in the LH2 umbilical feedline and recirculation line bellows. Heavy, but normal, ice had formed on the top and outboard side of the LH2 umbilical baggie. Unusually heavy ice build-up was present on the LH2 umbilical acreage, in the cavities, and along the LH2 feedline-to-umbilical interface. Cryogenic liquid drops and dense vapors emanated from the LH2 umbilical during the start of LH2 fast fill, but reduced significantly for the completion of fastfill and during stable replenish. Assessment by the Ice Team and Launch Management Team conluded that there was no LH2 leakage and that the cryogenic fluid was most probably liquid air caused by a crack in the umbilical TPS, which resulted in a thermal short. The dense vapors reappeared just prior to and during SSME ignition, and continued to envelope the umbilical through early ascent/tower clear.

IPR 29RV-0294 was written against a 2 foot longitudinal crack, 1/8-inch wide, in the intertank CPR foam beginning at the LH2 tank splice. The crack was located in the first stringer valley adjacent to the -Y thrust panel. There was no frost in the crack and no offset across the crack. This type of TPS crack is within the database from previous flights, was not a thermal or debris concern, and did not violate the NSTS-08303 criteria.

The RH SRB aft field joint primary heater circuit had failed early in the countdown. The joint cork was inspected during the T-3 walkdown and exhibited no signs of discoloration or defor-

mation. Subsequent post flight disassembly of the joint heater revealed the failure was most likely due to a short circuit within the heater cable connector (Reference KSC Malfunction Analysis Branch report MAB-071-89).

After a successful launch at 0957 EST, a post launch debris inspection of Pad 39B was performed. Other than three small portions of Q-felt plug (two 1/2-inch diameter and one 1-inch diameter), no significant flight hardware or TPS material was found. South holddown post shim material was intact, but had debonded from the shoe sidewall on holddown post #6. All of the north holddown post doghouse blast covers were in the closed position. A piece of frangible nut and NSI were recovered from holddown post #8 during stud removal. Overall, the facility sustained minimal damage.

A total of 97 film and 49 video items were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. Dense vapors emanated from the ET/ORB LH2 umbilical just prior to and during SSME ignition. These vapors continued to obscure the umbilical through tower clear. Some tiles on the base heat shield and RCS stingers were chipped by SSME acoustics. A Q-felt plug fell from the SSME #1 region at engine start. Six tile gap fillers from the -Z side of the SSME #1 engine mounted heat shield were shaken loose by SSME ignition. Small pieces of ET TPS were pulled loose from the right side of the GUCP plate cutout as the GUCP disconnected at T-0. Two NSI pieces fell from the aft skirt holddown post #8 stud hole at liftoff. Numerous pieces of debris fell from the vehicle during ascent. Most of these items have been identified as SSME frost, RCS paper covers, instafoam particles from the SRB aft skirts, ET/ORB umbilical ice, and pieces of foam from the ET intertank region. At T+61 seconds, an event was visible on the -Z side of the ET. A shower of particles or puff of vapor originated near the intertank/GUCP area, followed the aerodynamic streamlines aft, and dissipated near the 2058 ring frame. The event was most likely the breakup of a piece of TPS from a divot in the intertank area, but could also have been ice/frost from the GUCP or SLA 220 from the LH SRB -Z RSS antenna ramp.

The recovered Solid Rocket Boosters exhibited minimal damage, however several significant anomalies were noted. The RH frustum had 51 TPS debonds, all of which occurred over the sealant caps. The LH frustum had 31 TPS debonds, 29 of which occurred over the sealant caps. Removal of the debonded areas revealed adhesive failure of the epoxy topcoat to the sealant cap outer surface. This debond phenomenon was probably caused by incompatibility of the MSA-2 solvents in contact with the santoprene rubber cap material during spray operations. The TPS and Hypalon topcoat continues to have adhesion problems with widespread blistering, peeling, and cratering. Some of the blisters revealed adhesion of paint to the MSA indicating the formation of divots within the TPS. The LH -Z RSS antenna lost

a 6-1/2"x5-1/8" piece of SLA 220 TPS with signs of adhesive failure. Cracks appeared in a large K5NA closeout covering DFI cables on the RH SRB. This closeout, located at 90 degrees XB 850, had exceeded the allowable protuberance limit. Numerous GEI MSID labels were missing from both boosters. All field joint closeouts were undamaged and known void areas were still intact. Two factory joints, one on the FWD center case XB 1011.5 (180 degrees) and the second on the aft center case XB 1331.5 (90-270 degrees), experienced a debonding of the EPDM weather seals. Although the aft skirt holddown post debris container plungers were found properly seated, holddown posts #2, 4, 7, and 8 all lost fragments of frangible nut/NSI cartridges. The SRB nozzle extensions were severed at apogee for STS-29R in an attempt to minimize the damage caused to the parachutes by nozzle severance fragments. Unfortunately, this led to greater heating under the aft skirts and was probably the cause of the TVC damage. Post flight disassembly revealed the RH SRM igniter sustained a putty blowhole at approximately 300 degrees, an expected condition according to MTI. The LH SRM had no blowholes, a first since the return-to-flight mission STS-26R.

The Orbiter post landing inspection was conducted on 18-19 March 1989 at Ames-Dryden (EAFB) on the concrete Runway 22 and in the Mate/Demate Device (MDD). The Orbiter TPS sustained a total of 132 hits, of which 23 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 100 hits, with 18 greater than 1 inch. Based on these numbers, comparison to statistics from 21 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, and 27R which had damage from known debris sources), the total number of hits on the lower surface is slightly higher than normal. However, based on the severity of damage as indicated by surface area and depth, this flight is considered to be better than average.

During the post landing runway walkdown, two 10" long pieces of wire, one with a connector attached, were found. These wires originated from the right main landing gear wheel pressure strain gage system. At touchdown, these wires broke loose from the wheel and were thrown up into the Orbiter tile, causing a gouge 1-1/8 inch deep. Post landing inspection of the vehicle revealed that the debris plunger in the RH (LO2) EO-2 separation fitting debris container failed to seat properly in the 2-1/2" hole at ET/ORB separation. The plunger was jammed by two large pyro nut fragments. Two of the three umbilical plungers also did not have total closure. A concentration of tile hits were located aft of the LH2 umbilical. Similar patterns have been observed on previous flights and have been attributed to umbilical ice particles released at ET separation.

A total of 30 Post Launch Anomalies were observed during this review.

2.0 KSC ICE/FROST/DEBRIS TEAM ACTIVITIES

Team Composition: NASA KSC, NASA MSFC, NASA JSC, LSOC SPC, RI - DOWNEY, MMMSS - MAF, USBI - BPC, MTI - UTAH

Team Activities:

1) Prelaunch Pad Debris Inspection

Objective:	Identify and evaluate potential debris material/sources. Baseline debris and debris sources existing from previous launches.
Areas:	MLP deck, ORB and SRB flame exhaust holes, FSS, Shuttle vehicle external surfaces
Time:	L - 1 day
Requirements:	OMRSD S00U00.030 - An engineering debris inspection team shall inspect the shuttle and launch pad to identify/resolve potential debris sources. The prelaunch vehicle/pad configuration shall be documented/photographed.
Documents:	OMI S6444
Report:	Generate PR's and recommend corrective actions to pad managers.

2) Launch Countdown Firing Room 2

Objective:	Evaluate ice/frost accumulation on the shuttle vehicle and/or any observed debris utilizing OTV cameras.
Areas:	MLP deck, FSS, Shuttle vehicle external surfaces
Time:	T - 6 hours to Launch + 1 hour or propellant drainback
Requirements:	OMRSD S00FB0.005 - Monitor and video tape record ET TPS surfaces during loading through prepressurization.
Documents:	OMI S0007, OMI S6444
Report:	OIS call to NTD, Launch Director, and Shuttle managers. Generate IPR's.

3) Ice/Frost TPS and Debris Inspection

Objective:	Evaluate any ice formation as potential debris material. Identify and evaluate any ORB, ET, or SRB TPS anomaly which may be a debris source or safety of flight concern. Identify and evaluate any other possible facility or vehicle anomaly.
Areas:	MLP deck, FSS, Shuttle vehicle external surfaces
Time:	T - 3 hours (during 2 hour BIH)
Requirements:	OMRSD S00U00.020 - An engineering debris inspection team shall inspect the shuttle for ice/frost, TPS, and debris anomalies after cryo propellant loading. Evaluate, document, and photograph all anomalies. During shuttle walkdown inspect orbiter aft engine compartment (externally) for water condensation and/or ice formation in or between aft compartment tiles An IR scan is required during the shuttle inspection to verify ET surface temperatures. During shuttle walkdown, inspect ET TPS areas which cannot be observed by the OTV system.
Documents:	OMI S0007, OMI S6444
Report:	Briefing to NTD, Launch Director, Shuttle management; generate IPR's.

4) Post Launch Pad Debris Inspection

Objectives:	Locate and identify debris that could have damaged the Shuttle vehicle during launch.
Areas:	MLP deck, flame exhaust holes and trenches, FSS, pad surfaces and slopes, extension of trenches to perimeter fence, walkdown of the beach from Playlinda to Complex 40, aerial overview of inaccessible areas.
Time:	Launch + 3 hours (after pad safing, before washdown)
Requirements:	OMRSD S00U00.010 - An engineering debris inspection team shall perform a post launch pad/area inspection to identify any lost flight or ground systems hardware

and resultant debris sources. The post launch pad/area configuration shall be documented/photographed.

Documents: OMI S0007, OMI S6444

Report: Initial report to NTD and verbal briefing to Level II at L+8 hours; generate PR's.

5) Launch Data Review

Objective: Detailed review of high speed films video tapes, and photographs from pad cameras, range trackers, aircraft and vehicle onboard cameras to determine possible launch damage to the flight vehicle. Identify debris and debris sources.

Time: Launch + 1 day to Launch + 6 days

Requirements: OMRSD S00U00.011 - An engineering film review and analysis shall be performed on all engineering launch film as soon as possible to identify any debris damage to the space shuttle vehicle. Identify flight vehicle or ground system damage that could affect orbiter flight operations or future SSV launches.

Documents: OMI S6444

Report: Daily reports to Level II Mission Management Team starting on L+1 day through landing; generate PR's.

6) SRB Post Flight/Retrieval Inspection

Objective: Evaluate potential SRB debris sources. Data will be correlated with observed Orbiter post landing TPS damage.

Areas: SRB external surfaces (Hangar AF, CCAFS)

Time: Launch + 24 hours (after on-dock, before hydrolasing)

Requirements: OMRSD S00U00.013 - An engineering debris damage inspection team shall perform a post retrieval inspection of the SRB's to identify any damage caused by launch debris. Any anomalies must be documented/ photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Documents: OMI B8001
Report: Daily reports to Level II Mission Management Team. Preliminary report to SRB Disassembly Evaluation Team. Generate PR's.

7) Orbiter Post Landing Debris Damage Assessment

Objective: Identify and evaluate areas of damage to Orbiter TPS due to debris and correlate, if possible, source and time of occurrence. Additionally, runways are inspected for debris and sources of debris.
Areas: Orbiter TPS surfaces, runways
Time: After vehicle safing on runway, before towing
Requirements: OMRSD S00U00.040 - An engineering debris inspection team shall perform a prelanding runway inspection to identify, document, and collect debris that could result in orbiter damage. Runway debris and any facility anomalies which cannot be removed/corrected by the Team shall be documented and photographed; the proper management authority shall be notified and corrective actions taken.
Requirements: OMRSD S00U00.050 - An engineering debris inspection team shall perform a post landing runway inspection to identify and resolve potential debris sources that may have caused vehicle damage but was not present or was not identified during pre-launch runway inspection. Obtain photographic documentation of any debris, debris sources, or flight hardware that may have been lost on landing.
Requirements: OMRSD S00U00.060 - An engineering debris inspection team shall map, document, and photograph debris-related Orbiter TPS damage and debris sources.
Requirements: OMRSD S00U00.012 - An engineering debris damage inspection team shall perform a post landing inspection of the orbiter vehicle to identify any damage caused by launch debris. Any anomalies must be documented/

photographed and coordinated with the results of the post launch shuttle/pad area debris inspection.

Requirements: OMRSD V09AJ0.095 - An engineering debris inspection team shall perform temperature measurements of RCC Nose Cap and RCC RH Wing Leading Edge Panels 9 and 17.

Documents: OMI S0026, OMI S0027, OMI S0028

Report: Briefing to NASA Convoy Commander and generate PR's. Preliminary report to Level II on the day of landing followed by a preliminary update the next day.

8) Level II report

Objective: Compile and correlate data from all inspections and analyses. Results of the debris assessment, along with recommendations for corrective actions, are presented directly to Level II via SIR and PRCB. Paper copy of complete report follows in 3 to 4 weeks. (Ref NASA Technical Memorandum series).

3.0 PRE-TEST BRIEFING

The Ice/Frost/Debris Team briefing for launch activities was conducted on 12 March 1989 at 0800 hours with the following key personnel present:

C. Stevenson	NASA - KSC	Chief, ET Mechanical Systems Lead, Ice/Debris Team
G. Katnik	NASA - KSC	ET Mech/TPS, Ice/Debris Assessment, STI
S. Higginbotham	NASA - KSC	STI, Debris Assessment
B. Speece	NASA - KSC	ET Processing, Ice Assess
B. Bowen	NASA - KSC	ET Processing, "SURFICE"
P. Feamster	NASA - KSC	ET Processing, Debris Assess
J. Rivera	NASA - KSC	ET Processing, Debris Assess
A. Oliu	NASA - KSC	"SURFICE", Debris Assess
M. Bassignani	NASA - KSC	ET Processing, Ice Assess
M. Young	LSOC - SPC	ET Processing, Ice Assess
F. Huneidi	NASA - MSFC	TPS & Ice Assessment
D. Andrews	NASA - MSFC	Debris Assessment
D. Huntsman	NASA - JSC	Level II Debris Rep
Z. Byrns	NASA - JSC	Level II Integration
C. Gray	MMC - MAF	ET TPS & Materials Design
S. Copsey	MMC - MAF	ET TPS Testing/Certif
J. McClymonds	RI - Downey	Support LVL II Integration
K. Mayer	RI - LSS	Debris Assessment
A. Fazio	RI - LSS	Debris Assessment
H. Novak	USBI - PSE	SRB Processing,Debris Assess
J. Maw	MTI - Utah	SRM Plant Representative
G. Meeks	NASA - SSC	STI Operations
C. Thurman	NASA - SSC	STI Operations

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

The pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 12 March 1989 from 0930 - 1330 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (8 th flight), ET-36 (LWT-29), and BIO-31. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and new vehicle configurations.

There were no major vehicle anomalies. The External Tank hydrogen fire detection system (butcher paper) was missing from the vertical strut at position #3 and #4, and severely ripped at positions #1, #2, and #6. This occurred during high winds associated with a recent weather front and was documented on PR-ET-36-TS-0108.

Several bolts on the SSME water suppression line were loose. All brackets on this line should have locknuts. One bracket on the north side near holddown post #5 had only one nut. Two 1-inch bolts were loose on the northeast corner of the MLP raised deck. One of these bolts fits in the access hatch cover. The grounding lugs for the handrails had not been torqued. An access cover adjacent to holddown post #5 had not been tightened. Bolts on the portable crank stanchion cover near holddown posts #2 and #6 were loose. The washer on the top left bolt of the holddown post #2 access cover could be rotated.

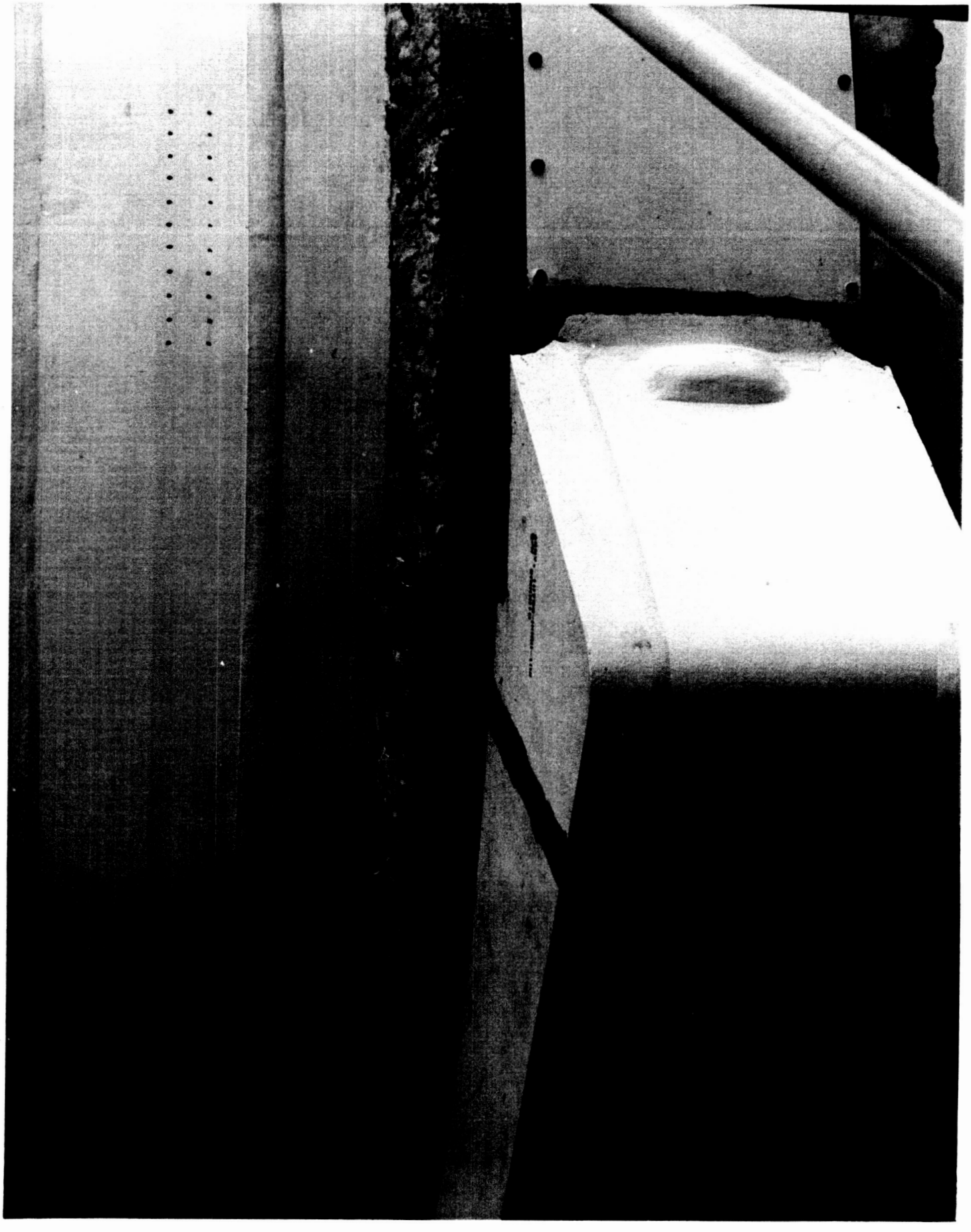
The electrical access cover on the northeast corner of the MLP deck outside the gutter was loose and could be rotated. An electrical control box cover between the Portable Purge Unit electrical outlets on the northwest side of the MLP was also loose.

All holddown post haunches show dirt and corrosion. Plastic covers had fallen into the handrail holes. K5NA debris lay on the deck under both SRB IEA's. A broken grounding strap was attached to the MLP deck adjacent to holddown post #5. Optical targets were loose on holddown post #6.

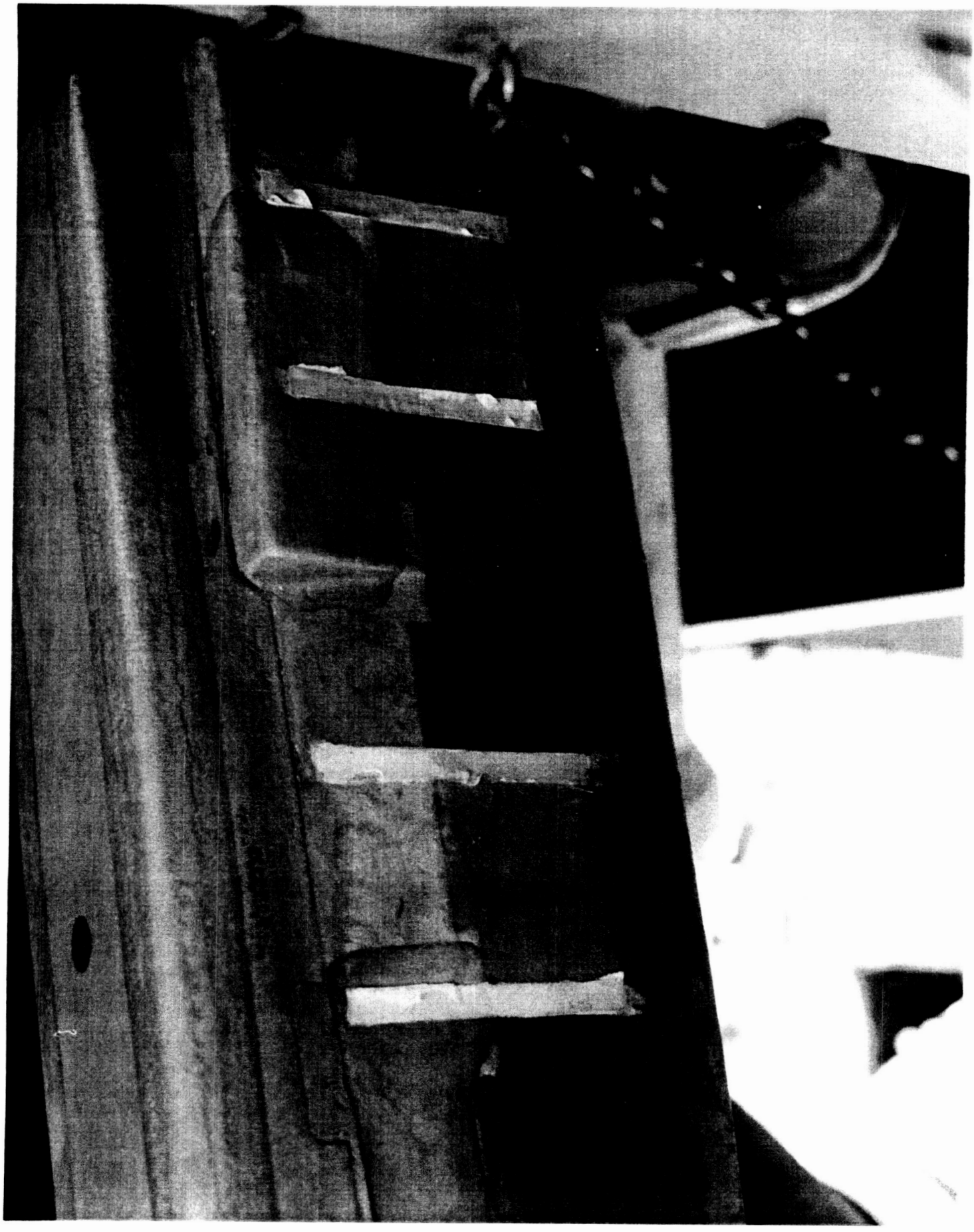
Elsewhere on the deck, a large loose chunk of concrete had broken away from the northwest corner of the LH2 TSM base. A section of blast shield decking near Camera E-27 was pinned rather than bolted to the MLP deck. Water trough part tags/streamers need to be removed. The southwest MLP deck drain gutter was clogged with debris.

An overhead cable tray outside the elevator on the FSS 135 foot level was not secured.

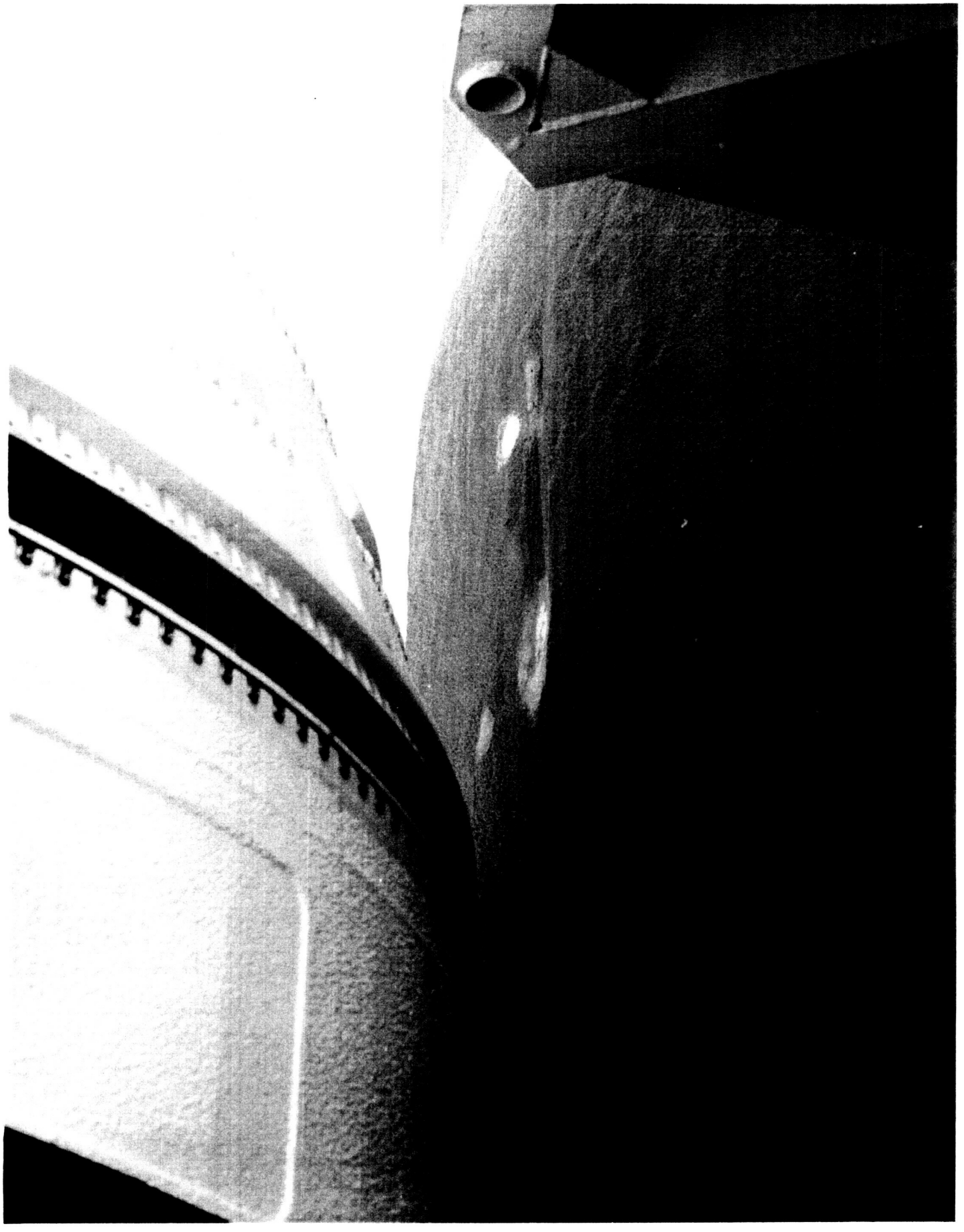
Cleanup of the MLP deck and pad surface was in progress at the time of the inspection. The facility discrepancies listed above were transferred to the pad leader for resolution prior to vehicle tanking.



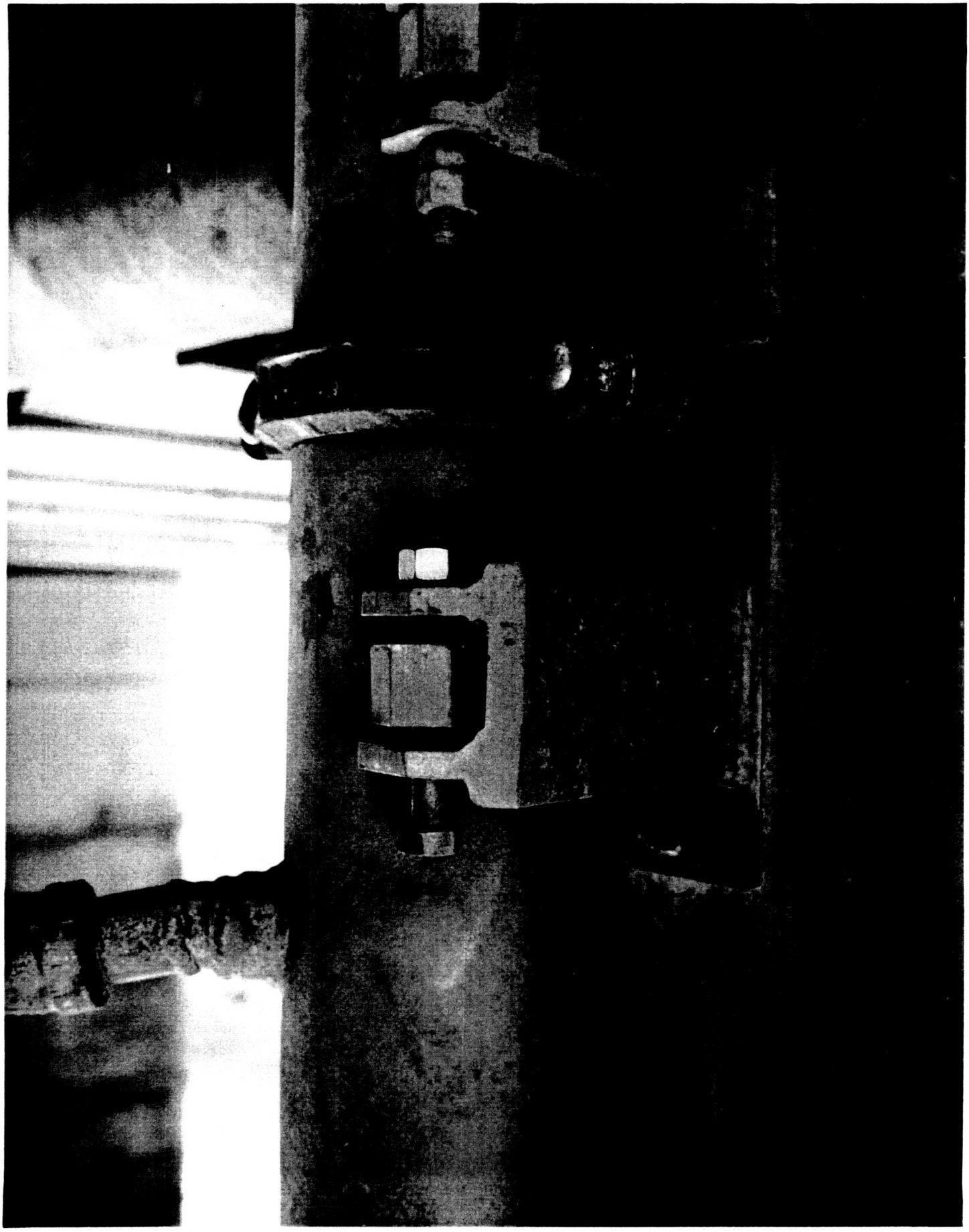
K5NA REAPPLIED DAY BEFORE LAUNCH. CURE TIME WAS WAIVED.
NOTE JOINT PROTECTION SYSTEM CORK VENT HOLES



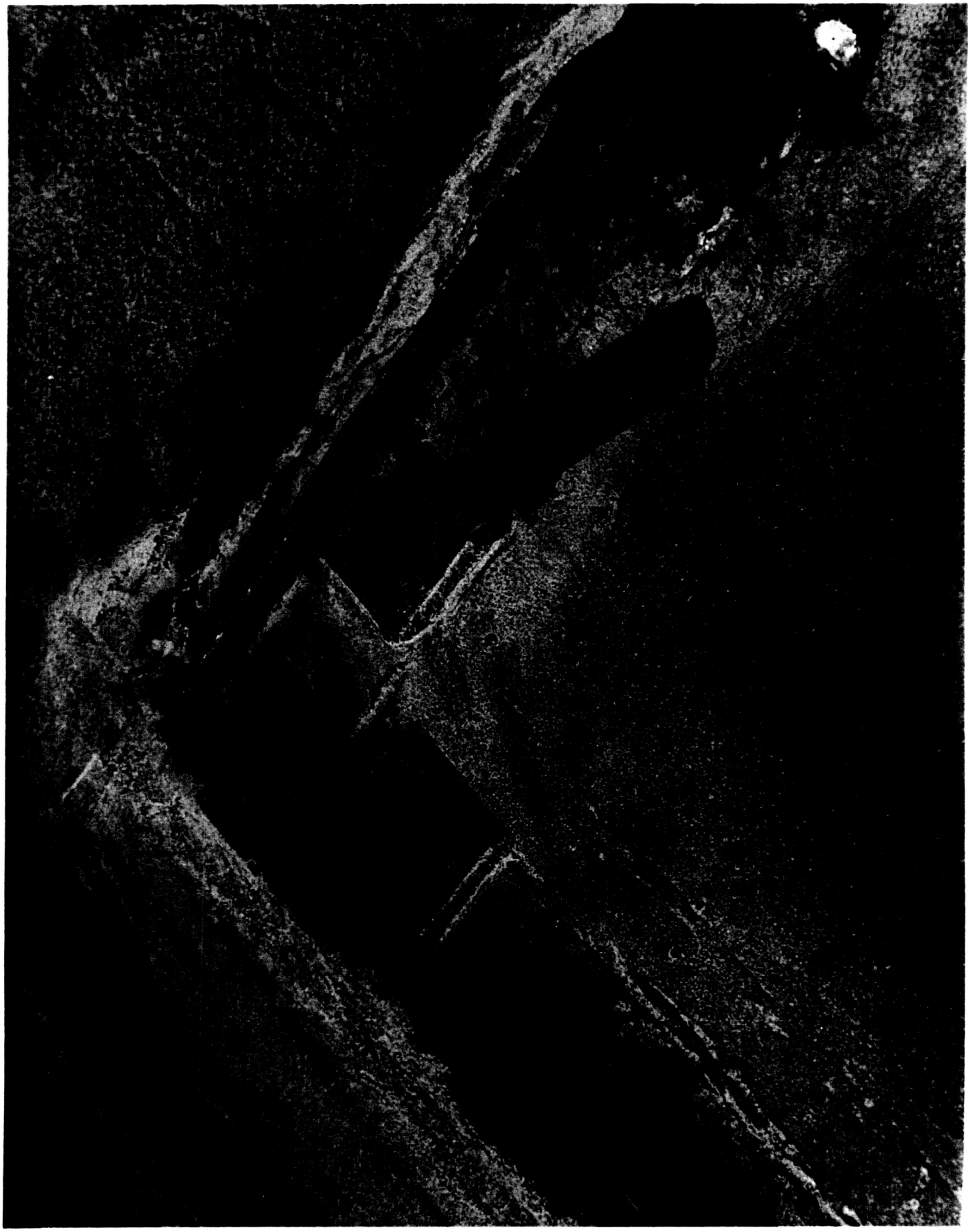
MISSING PIECES OF BUTCHER PAPER FROM HYDROGEN FIRE DETECTION SYSTEM DUE TO HIGH WINDS



VENDOR REPAIR TO -Y THRUST PANEL TPS ACREAGE



LOOSE BOLT ON FIREX PIPE ADJACENT TO SSME EXHAUST HOLE



LOOSE BOLT ON MLP DECK ACCESS COVER

LOOSE CONCRETE AT NORTHWEST CORNER OF LH2 TSM BASE

ORIGINAL PAGE
COLOR PHOTOGRAPH

4.0 LAUNCH

STS-29R was successfully launched at 0957 on 13 March 1989.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryo-loaded vehicle was performed on 13 March 1989 from 0245 to 0550 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no violations of NSTS-08303 or Launch Commit Criteria. Ambient weather conditions at the time of the inspection were:

Temperature:	57.7 F
Relative Humidity:	97.0 %
Wind Speed:	8.6 Knots
Wind Direction:	245 Degrees

The portable STI infrared scanner was utilized to obtain surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

4.2 ORBITER OBSERVATIONS

No Orbiter tile anomalies were observed. The average Orbiter surface temperature ranged from 58 to 62 degrees F. The surface temperatures of the SSME engine mounted heat shields were recorded as 57 degrees F for SSME #1, 52 degrees F for SSME #2, and 56 degrees F for SSME #3. Some frost was present at the engine to heat shield interface of SSME #1 and SSME #2 while SSME #3 had none. No condensate was present on the aft heat shield or drain holes. The payload bay door carrier panels/FRSI plugs for the strongbacks were verified to be installed.

4.3 SRB OBSERVATIONS

The STI portable infrared scanner recorded both RH and LH SRB case surface temperatures between 57 and 60 degrees F. The IR scanner showed no cooling effects on the SRB's from the External Tank. Temperatures for the SRB field joints/heaters ranged from 66 to 78 degrees F. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 62 degrees F.

All thermal curtain tape was in place and all closeouts were intact. The RH SRB aft field joint primary heater circuit had failed early in the countdown and a short to the booster case was suspected. The joint cork was inspected externally during the walkdown and exhibited no signs of discoloration, deformation, etc. The secondary heater circuit was activated and performed nominally. No SRB anomalies were observed.

FIGURE 1. **INFRA-RED SCANNER SSV SUMMARY DATA**

TIME: 0248 - 0454
DATE: 13 March 1989
VEH. STS- 29R launched 9:57 a.m.

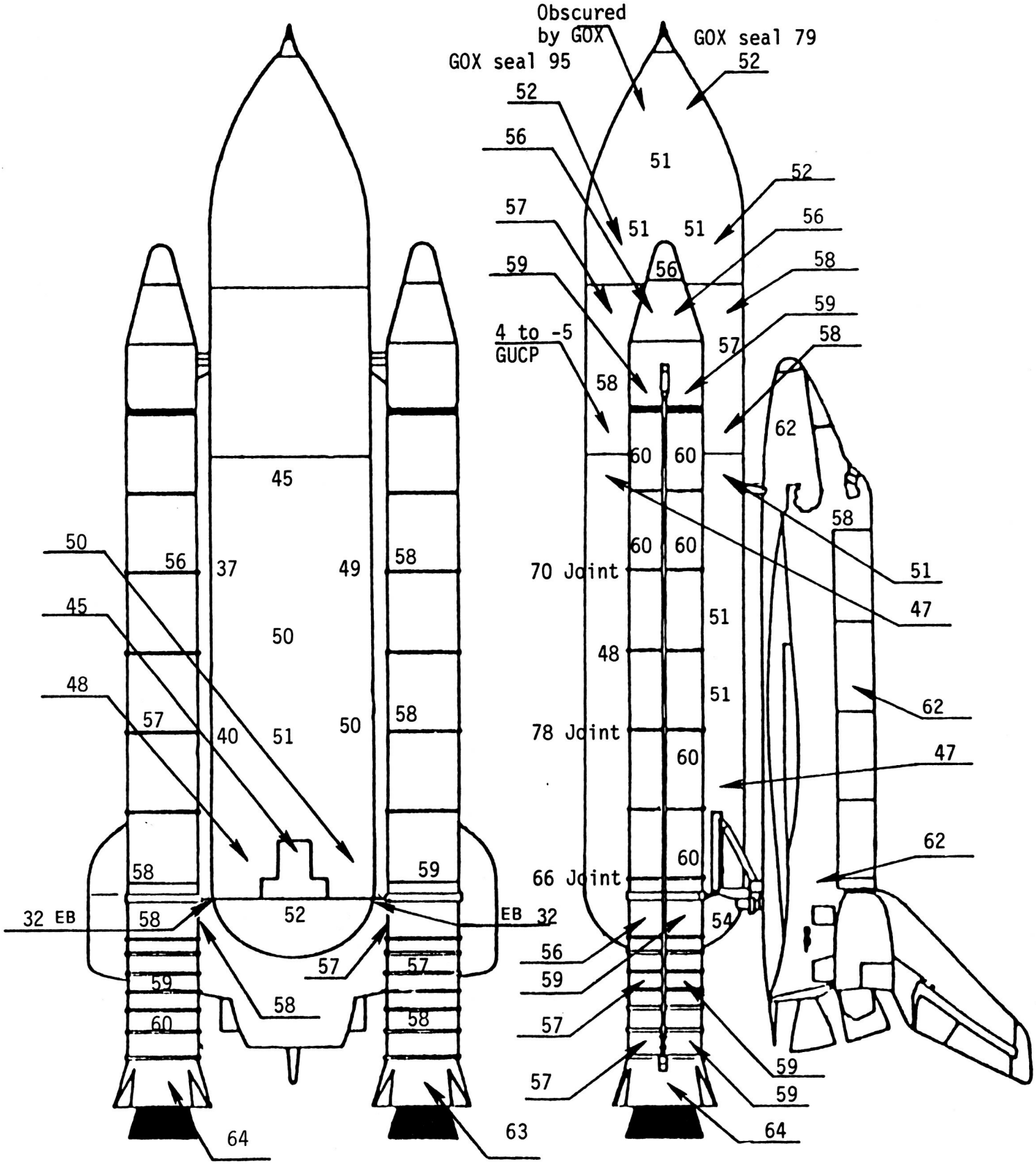
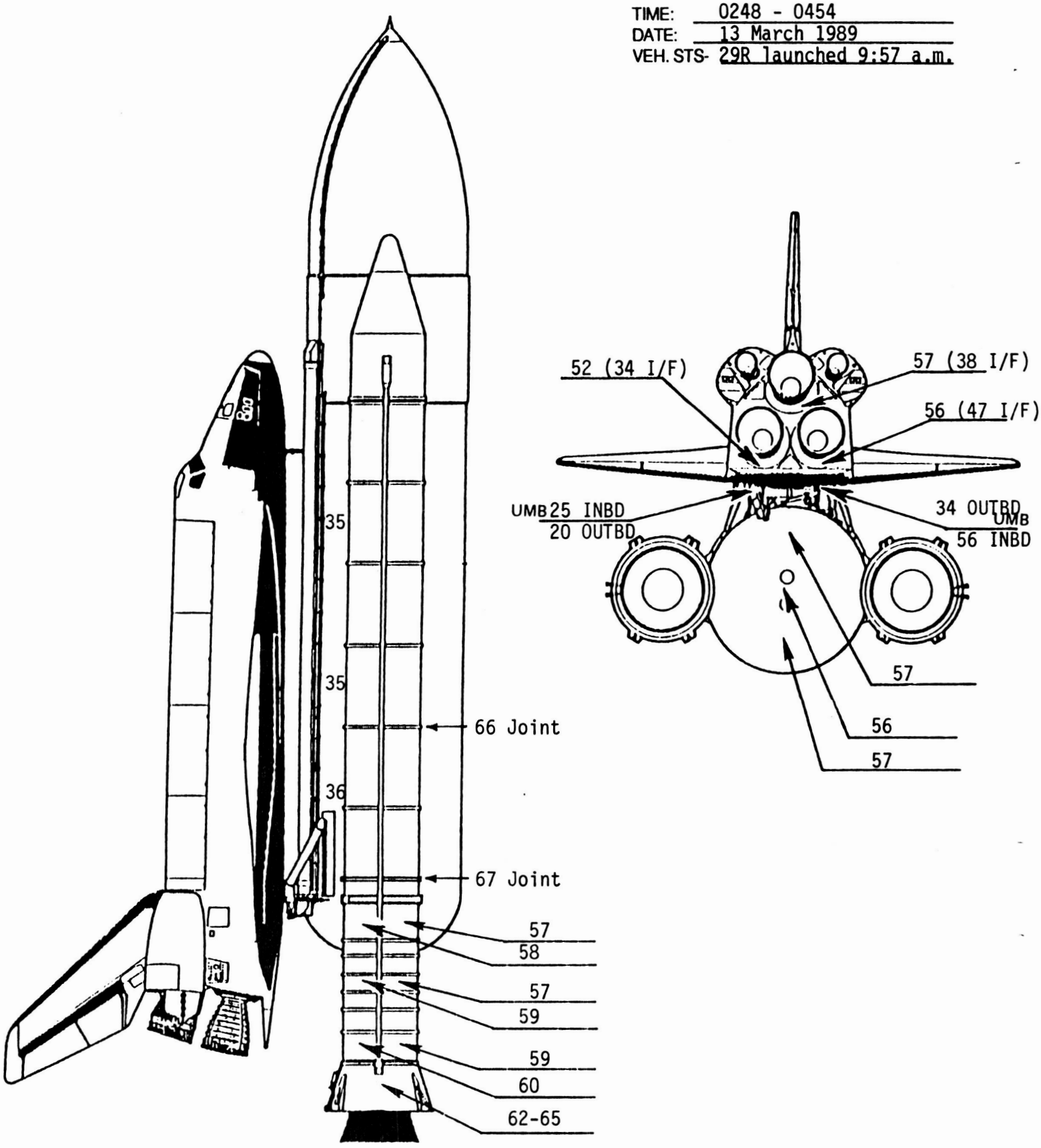


FIGURE 2. **INFRA-RED SCANNER SSV SUMMARY DATA**



4.4 EXTERNAL TANK OBSERVATIONS

The ice/frost SURFICE computer program was run from 2330 to 0957 hours and the results tabulated in Figures 3, 4, and 5. The program predicted condensate with no ice accumulation on all ET TPS acreage.

The tumble valve cover was in flight configuration. No leakage had occurred around the GOX seals and there were no anomalies on the ogive. Condensate, but no ice/frost, was present on the LO2 tank. The average temperature of the LO2 tank was 51 degrees F.

Condensate run-on was visible on the intertank. The I/T side of both flanges had accumulated frost for about 6 inches in length along the -Z side stringers. The average surface temperature of the intertank ranged from 54 to 58 degrees F.

IPR 29RV-0294 was written against a 2 foot longitudinal crack 1/8-inch wide in the intertank CPR TPS beginning at the LH2 tank splice (Figure 6). The crack was located near the GUCP in the first stringer valley adjacent to the -Y thrust panel. There was no frost in the crack. The depth could not be determined and there was no offset across the crack. Experience obtained in developmental tests indicate no concerns for SOFI cracks that are linear and show no offset. The crack is within the data base from previous flights - a similar crack in this location occurred on STS-6/ET-8. Panel deformation during ET fabrication and mate to SRB's coupled with thermally induced hoop compression during cryoload can result in local flexure and is the probable cause of this SOFI crack. There is no thermal or debris concern for this type of TPS crack and no violation of NSTS-08303 criteria.

Some condensate on the intertank continued to run down onto the LH2 tank upper barrel. Small patches of ice/frost had accumulated on the LH2 tank in the +Y+Z and +Y-Z quadrants (from the LH2 cable tray past the RH SRB attach point). The ice/frost was less than 1/16-inch thick and acceptable per the nomographs and NSTS-08303 criteria. These patches later were diminished by the sun and wind, and were nearly gone by launch. The average temperature of the LH2 tank was 45 to 51 degrees F. An ice/frost line was visible along the PAL ramp interface. Hard ice had accumulated under the feedline support brackets and in the feedline bellows. Ice/frost was visible in the crotch area of the RH thrust strut.

Frost fingers had formed on the ET/ORB LO2 umbilical purge vents, but ice/frost build-up on the umbilical acreage and in the cavities was less than usual.

Typical amounts of ice were visible in the LH2 umbilical feedline and recirculation line bellows. Uninsulated portions of the feedline were covered by frost. Frost fingers had formed on

STS – 29R	TEST: S0007 Launch																									
															DATE: 3/13/89				T-0 TIME: 0957 DATE: 3/13/89						
ORBITER	ET	SRB	MLP	PAD	LO_2 CHILLDOWN TIME: 2355 FAST FILL TIME: 0034 SLOW FILL TIME: 0020 REPLENISH TIME: 0237										LH_2 CHILLDOWN TIME: 2344 FAST FILL TIME: 0020 SLOW FILL TIME: 2351 REPLENISH TIME: 0138													
OV- 103	36	B10-31	2	39B																						
LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
2330	59	75	51.1	8	247	II	4.72	46.3	.0014	.0716	II	4.72	41.1	.0027	.0444	II	2.56	33.1	.0025	.0036	II	10.88	46.9	.0026	.136
0000	58.6	79	51.1	7	244	II	4.13	45.8	.0017	.0635	II	4.13	40.1	.0029	.0364	III	2.24	31.9	.0025	.0005	II	9.52	46.4	.0032	.118
0015	58.4	82	52.9	8	238	II	4.72	46.9	.0019	.0755	II	4.72	41.8	.0031	.0480	II	2.56	33.6	.0028	.0056	II	10.88	47.7	.0034	.144
0030	59.2	84	54.4	9	235	II	5.31	48.9	.0020	.0933	II	5.31	44.2	.0031	.0654	II	2.88	36.4	.0031	.0159	II	12.24	49.1	.0037	.180
0045	59.1	85	54.6	8	239	II	4.72	48.3	.0021	.0829	II	4.72	43.2	.0034	.0552	II	2.56	34.9	.0029	.0101	II	10.88	49.0	.0038	.158
0100	57.9	87	54.1	7	241	II	4.13	46.5	.0021	.0672	II	4.13	40.9	.0033	.0398	II	2.24	32.2	.0029	.0006	II	9.52	47.2	.0040	.126
0115	58.3	90	55.4	8	237	II	4.72	48.3	.0024	.0832	II	4.72	43.2	.0036	.0554	II	2.56	34.9	.0032	.0092	II	10.88	49.1	.0044	.159
0130	58.4	91	55.8	8	238	II	4.72	48.6	.0024	.0849	II	4.72	43.5	.0037	.0570	II	2.56	35.2	.0032	.0108	II	10.88	49.4	.0045	.162
0145	58.3	92	56.0	9	238	II	5.31	49.4	.0025	.0964	II	5.31	44.7	.0039	.0683	II	2.88	36.8	.0034	.0172	II	12.24	50.2	.0047	.187
0200	58.3	93	56.3	9	239	II	5.31	49.5	.0027	.0976	II	5.31	44.9	.0039	.0694	II	2.88	36.9	.0035	.0178	II	12.24	50.4	.0048	.189
0215	58.4	94	56.7	8	241	II	4.72	49.2	.0026	.0880	II	4.72	44.1	.0039	.0599	II	2.56	35.7	.0034	.0126	II	10.88	49.9	.0049	.168
0230	58.8	94	57.1	8	235	II	4.72	49.6	.0026	.0906	II	4.72	44.5	.0040	.0625	II	2.56	36.3	.0034	.0143	II	10.88	50.4	.0049	.173
0245	58.2	95	56.8	7	230	II	4.13	48.3	.0026	.0763	II	4.13	42.7	.0038	.0485	II	2.24	33.9	.0032	.0059	II	9.52	49.1	.0049	.143
0300	58.2	96	57.1	9	234	II	5.31	49.9	.0028	.1003	II	5.31	45.3	.0042	.0719	II	2.88	37.4	.0036	.0193	II	12.24	50.8	.0051	.194
0315	57.7	96	56.6	8	240	II	4.72	48.7	.0027	.0855	II	4.72	43.6	.0039	.0576	II	2.56	35.22	.0034	.0108	II	10.88	49.5	.0050	.164

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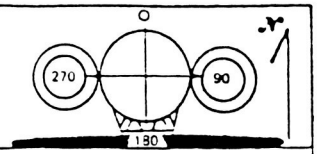
FIGURE 3. Ice/Frost Computer Predictions

STS – 29R	TEST: S0007 Launch	DATE: 3/13/89	T-0 TIME: 0957 DATE: 3/13/89

ORBITER	ET	SRB	MLP	PAD	LO_2	LH_2
OV– 103	36	B10-31	2	39B	CHILLDOWN TIME: 2355 FAST FILL TIME 0034 SLOW FILL TIME: 0020 REPLENISH TIME 0237	CHILLDOWN TIME: 2344 FAST FILL TIME 0020 SLOW FILL TIME: 2351 REPLENISH TIME 0138



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0330	57.8	97	56.9	9	247	II	5.31	49.7	.0028	.0966	II	5.31	45.0	.0042	.0703	II	2.88	37.1	.0036	.0182	II	12.24	50.6	.0052	.1919
0345	58.0	97	57.1	8	244	II	4.72	49.2	.0027	.0885	II	4.72	44.1	.0041	.0606	II	2.56	35.8	.0034	.0127	II	10.88	50.1	.0052	.1697
0400	57.5	98	56.9	8	249	II	4.72	48.9	.0028	.0862	II	4.72	43.7	.0039	.0582	II	3.44	39.1	.0039	.0283	II	9.68	48.9	.0051	.1441
0415	57.8	98	57.2	9	245	II	5.31	49.9	.0029	.0996	II	5.31	45.2	.0043	.0714	II	2.88	37.2	.0037	.0188	II	12.24	50.7	.0053	.1941
0430	57.7	98	57.1	9	243	II	5.31	49.8	.0029	.0989	II	5.31	45.1	.0043	.0707	II	2.88	37.1	.0037	.0183	II	12.24	50.6	.0053	.1928
0445	57.7	98	57.1	9	245	II	5.31	49.8	.0029	.0989	II	5.31	45.1	.0043	.0707	II	2.88	37.1	.0037	.0183	II	12.24	50.6	.0053	.1928
0500	57.7	99	57.4	9	243	II	5.31	49.9	.0029	.1001	II	5.31	45.3	.0043	.0718	II	2.88	37.3	.0037	.0189	II	12.24	50.8	.0054	.1950
0515	57.7	99	57.4	10	244	II	5.90	50.5	.0030	.1115	II	5.90	46.2	.0044	.0829	II	3.20	38.6	.0039	.0253	II	13.60	51.4	.0055	.2198
0530	57.3	99	57.0	10	247	II	5.90	50.1	.0030	.1085	II	5.90	45.8	.0044	.0800	II	3.20	38.1	.0038	.0234	II	13.60	50.9	.0055	.2141
0545	57.5	99	57.2	10	248	II	5.90	50.3	.0030	.1099	II	5.90	45.9	.0044	.0815	II	4.30	41.8	.0043	.0456	II	12.10	50.5	.0054	.1898
0600	56.9	100	56.9	9	247	II	5.31	49.2	.0029	.0955	II	5.31	44.5	.0043	.0673	II	2.88	36.5	.0037	.0159	II	12.24	50.1	.0055	.1867
0615	57.0	100	57.0	10	246	II	5.90	49.9	.0031	.1073	II	5.90	45.6	.0044	.0789	II	3.20	37.9	.0039	.0226	II	13.60	50.8	.0056	.2122
0630	56.8	100	56.8	9	249	II	5.31	49.1	.0029	.0948	II	5.31	44.4	.0043	.0666	II	3.87	39.9	.0041	.0343	II	10.89	49.3	.0054	.1615
0645	56.7	100	56.7	11	253	II	6.49	50.1	.0031	.1159	II	6.49	46.0	.0045	.0874	II	4.73	42.1	.0044	.0497	II	13.31	50.4	.0056	.2029
0700	56.6	100	56.6	12	254	II	7.08	50.4	.0032	.1249	II	7.08	46.6	.0046	.0974	II	5.16	42.9	.0045	.0569	II	14.52	50.7	.0056	.2225

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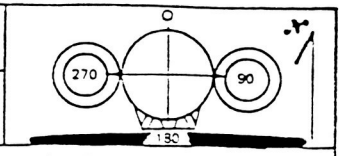
FIGURE 4. Ice/Frost Computer Predictions

STS- 29R	TEST: S0007 Launch									DATE: 3/13/89		T-0 TIME 0957 DATE 3/13/89		
ORBITER	ET	SRB	MLP	PAD	LO_2 CHILLDOWN TIME: 2355	SLOW FILL TIME: 0020	FAST FILL TIME: 0034	REPLENISH TIME: 0237	LH_2 CHILLDOWN TIME: 2344	SLOW FILL TIME: 2351	FAST FILL TIME 0020	REPLENISH TIME 0138		
OV- 103	36	B10-31	2	39B										



LOCAL TIME	CONDITIONS					LO_2 TANK STA 370 TO 540					LO_2 TANK STA 550 TO 852					LH_2 TANK STA 1130 TO 1380					LH_2 TANK STA 1380 TO 2058				
	TEMP. °F	REL HUM. %	DEW PT °F	WIND VEL KNTS	WIND DIR DEG	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR	REGION	LOCAL VEL KNTS	SOFI TEMP °F	COND RATE IN/HR	ICE RATE IN/HR
0715	56.8	100	56.8	10	250	II	5.90	49.7	.0031	.1058	II	5.90	45.4	.0044	.0775	II	4.30	41.2	.0043	.0424	II	12.10	49.9	.0055	.1825
0730	57.0	100	56.9	9	255	II	5.31	49.2	.0029	.0953	II	5.31	44.5	.0043	.0673	II	3.87	40.1	.0041	.0349	II	10.89	49.4	.0054	.1627
0745	57.7	100	57.7	7	256	II	4.13	48.6	.0029	.0779	II	4.13	42.9	.0041	.0499	II	3.01	37.9	.0038	.0222	II	8.47	48.6	.0052	.1272
0800	58.3	100	58.3	9	261	II	5.31	50.8	.0031	.1055	II	5.31	46.2	.0045	.0769	II	3.87	41.8	.0043	.0426	II	10.89	50.9	.0056	.1795
0815	59.1	100	59.1	10	266	II	5.90	52.3	.0031	.1236	II	5.90	48.0	.0047	.0947	II	4.30	43.9	.0045	.0561	II	12.10	52.5	.0057	.2132
0830	59.7	100	59.7	9	263	II	5.31	52.4	.0031	.1157	II	5.31	47.8	.0046	.0869	II	3.87	43.5	.0044	.0506	II	10.89	52.5	.0057	.1968
0845	60.5	98	59.9	9	261	II	5.31	52.9	.0031	.1193	II	5.31	48.4	.0045	.0904	II	3.87	44.1	.0044	.0534	II	10.89	53.1	.0055	.2025
0900	60.9	97	60.1	10	256	II	5.90	53.7	.0031	.1341	II	5.90	49.6	.0046	.1049	II	4.30	45.6	.0045	.0644	II	12.10	53.9	.0055	.2306
0915	62.0	94	60.3	9	238	II	5.31	53.8	.0028	.1254	II	5.31	49.4	.0043	.0964	II	2.88	41.8	.0038	.0357	II	12.24	54.6	.0052	.2413
0930	63.0	91	60.4	11	253	II	6.49	55.4	.0027	.1560	II	6.49	51.6	.0043	.1265	II	4.73	47.9	.0044	.0812	II	13.31	55.5	.0049	.2706
0945	64.0	88	60.4	10	239	II	5.90	55.4	.0025	.1462	II	5.90	51.3	.0041	.1168	II	3.20	44.3	.0038	.0484	II	13.60	56.1	.0045	.2381
(T-0) 0957	64.5	86	60.3	8	249	II	4.72	54.4	.0024	.1194	II	4.72	49.6	.0030	.0906	II	3.44	45.3	.0038	.0549	II	9.68	54.3	.0044	.1978
AVG.	58.6	94	56.9	9	W			49.9					45.3					39.7					50.6		

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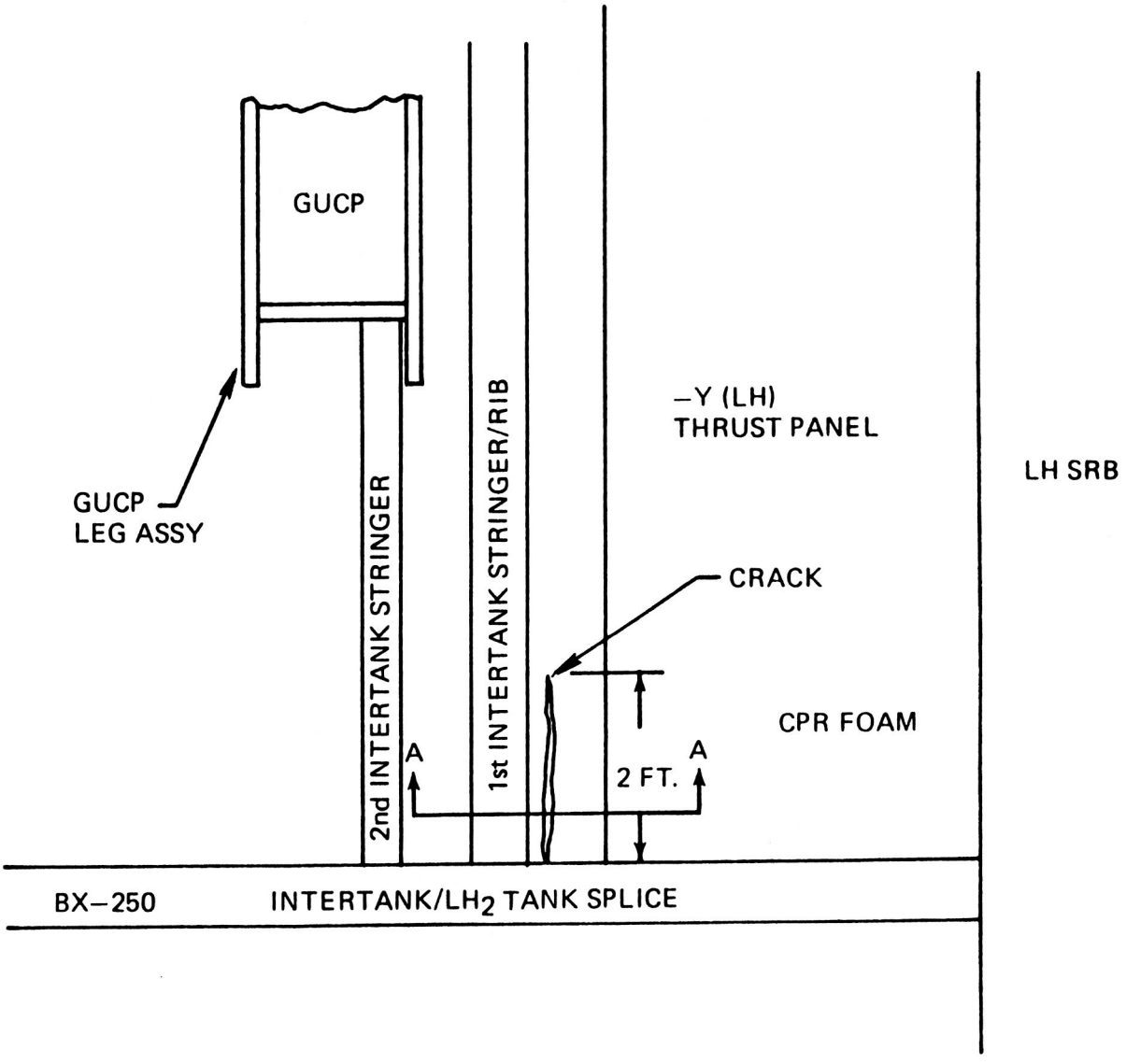
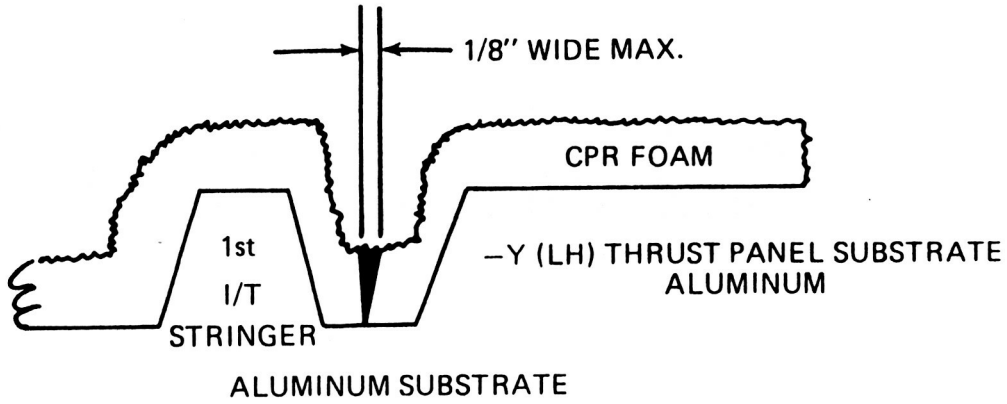
FIGURE 5. Ice/Frost Computer Predictions

FIGURE 6. Crack in ET Intertank TPS





SECTION A–A

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the purge vents. Heavy, but normal, ice was present on the top and outboard side of the LH2 umbilical baggie. Heavy ice build-up had accumulated on the umbilical acreage, in the cavities, and along the LH2 feedline-to-umbilical interface, which is not typical.

At the start of LH2 tank fastfill, dense vapors emanated from the ET/ORB LH2 umbilical. Cryogenic liquid drops trailing vapor fell from the umbilical well area toward the MLP deck before vaporizing completely. The vapors and cryogenic liquid drops diminished significantly for the completion of fastfill and during stable replenish. At the time of the Ice Team inspection, the LH2 umbilical was intermittently obscured by dense vapors, but not in amounts greater than previously observed on STS-26R and 27R (Table 1 compiles the observations from OTV cameras 109 and 163). There was no evidence of a LH2 leak, condensate run-off, or any liquid air generation during the Ice Team Inspection.

Table 1. ET/ORB LH2 Umbilical Cryo Liquid/Vapors Timeline

Local Time	Observation/Event
00:20	LH2 tank fastfill
00:31	Liquid droplets with vapor trails fall from umbilical. During next 2 minutes, droplets increase in size and fall long distance toward MLP deck while trailing vapors.
00:54	Liquid droplets less and less frequent
01:02	Liquid concentration falls from 10 o'clock umbilical position (looking towards ET), lands on umbilical cable tray, and flows along tray.
01:38	LH2 tank stable replenish
01:02-01:46	Liquid droplets/concentration fall from umbilical (previously noted location) at varying time intervals.
01:12	Half-inch diameter particle falls from underside of recirculation line.
03:19	Ice Team is on MLP zero level. Tripod leg is visible under cable tray vent hole.
03:26	Ice Team comes into FOV. Ice on umbilical baggie has receded (termination line moved forward) compared to previous observation.

04:16	Condensate drips steadily from recirc line, feedline, and umbilical. Ice/frost formations on umbilical and baggie (fwd and outboard sides) have reached maximum growth. Presence of gasses, vapors, and condensate dripping are consistent with previous cryo load data.
04:48	Area that previously had dripping cryogenic liquid now exhibits only venting of umbilical cavity purge gas.
05:14	Dense vapors emanate from feedline bellows and umbilical.
05:45	Frost particle comes loose from umbilical/ baggie, falls, and partially deposits on pressurization line bellows.
08:50	Quantity of vapors much, much less than earlier observations.
09:57 (T-0)	Just prior to ignition, a particle (probably frost) falls and strikes ORB LH wing. Particles and dense vapors originate from umbilical well area and are drawn into sound suppression water in SSME exhaust hole. At SSME ignition, numerous particles and dense vapors continue to emanate from umbilical well. Particles are 'thrown' out at 45 degree angle and are drawn into SSME exhaust hole by aspiration.
	Particles continue to be emitted from umbilical area through early ascent. Dense vapors obscure umbilical through tower clear.

Review of available data suggests the forward outboard side of the ET/ORB LH2 umbilical TPS contained a defect that exposed a cryogenic surface to the atmosphere causing the formation of super-cooled liquid air (cryopumping). At one particular point in the OTV 109 footage, liquid air was propelled by the upper outboard umbilical cavity purge vent and gave the appearance the liquid was expelled from inside the purge cavity. However, review of available data showed no other indications of possible purge gas liquefaction. The liquid drops, with vapor trails, fell as far as the aft edge of the body flap before vaporizing completely, and the behavior of the liquid dropping onto the umbilical cable tray surface, support the conclusion that the liquid was cryogenic. Since colder cryogenic liquids, such as helium or hydrogen, produce larger vapor formations in

the immediate area of the residual cryogenic liquid, the only possibilities from available sources for this liquid are nitrogen/air.

The ice/frost accumulation on the ET/SRB fittings from the tank interface outboard to the strut pin hole was typical. There was no ice/frost/condensate on the rest of the fitting or the ET/SRB struts.

Heavy condensate was dripping from the aft dome. An iceball 1-inch in diameter protruded 1/2 inch from the +Z side of the manhole cover. This ice had melted by launch.

The summary of ice/frost team observation anomalies consists of 12 items. Anomaly 001 documented torn butcher paper at positions #1 and #2, and missing butcher paper at #3 and #4 (ref PR-ET-36-TS-0108).

The heavy/dense vapors and occasional liquid emanating from the ET/ORB LH2 umbilical were recorded on Anomaly 002. Cryogenic liquid was only observed during LH2 fastfill. Assessment by the Ice Team and Launch Management Team concluded there was no LH2 leakage and that the dripping fluid/vapors was most probably liquid air caused by a crack or debond in the umbilical TPS resulting in a cryogenic cold short.

Ice/Frost at the ET/ORB LH2 interface was acceptable per NSTS 08303 (Anomaly 003).

Anomaly 004 documented excessive ice build-up on the ET/ORB LH2 umbilical and was accepted per NSTS-08303.

Ice/frost accumulation in the +Y thrust strut crotch area was recorded on Anomaly 005. It is acceptable per NSTS-08303.

Acreage ice/frost patches on the +Y-Z side of the LH2 tank are less than 1/16-inch thick and acceptable per the Launch Commit Criteria Appendix F and NSTS-08303 (Anomaly 006).

Anomaly 007 documented light frost on the GOX vent ducts. No icicles or frost fingers formed and the condition was acceptable per NSTS-08303.

Frost along the LH2 tank PAL ramp interface and on the acreage adjacent to the ramp was recorded on Anomaly 008. This frost melted prior to launch.

Frost formation between intertank stringers in the -Y-Z quadrant at XT 1151 was acceptable per NSTS-08303 (Anomaly 009).

Anomaly 010 documented the 2-foot crack in the intertank SOFI near the -Y thrust panel (reference IPR 29RV-0294) and was acceptable as an explained condition.

An iceball formed on the closeout TPS of the +Z manhole cover, but was removed later by condensate run-off (Anomaly 011).

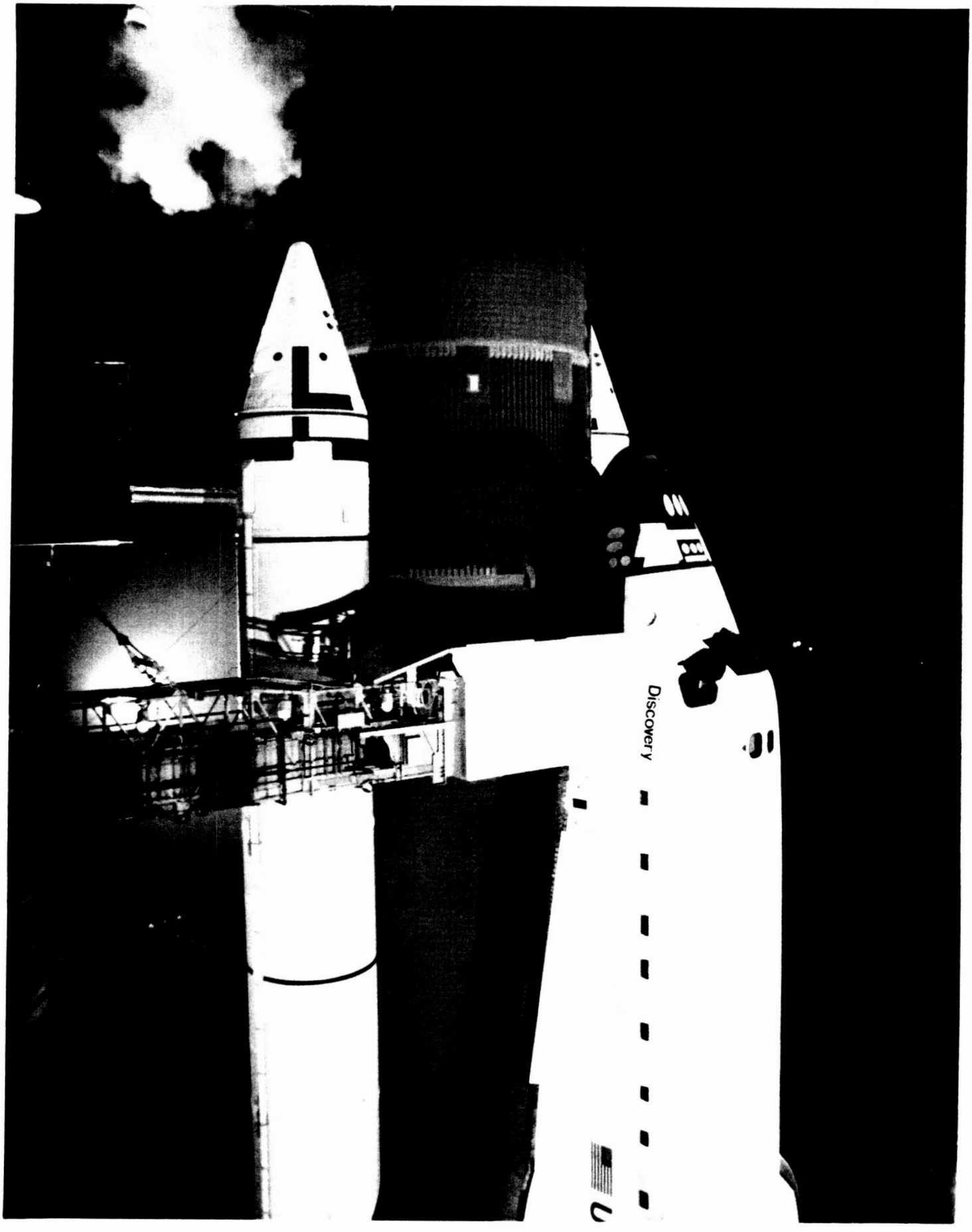
Frost accumulation in the intertank -Z stringers at the LO2 tank to intertank splice was recorded on Anomaly 012 and found acceptable per NSTS-08303.

Observed ET Post Launch Anomalies are listed in section 10.0.

4.5 FACILITY OBSERVATIONS

No anomalies were observed on the launch facility, access arms, or pad. Ice/frost had accumulated on the LH2 and LO2 T-0 umbilicals, but there were no leaks. The return-to-flight modifications to the GH2 vent arm prevented ice from forming, but the IR scanner detected some cold areas where the insulation jacket was not flush against the vent line. The GUCP had accumulated some frost on the tank side of the interface. The GOX ducts were venting almost equally with the south duct venting slightly more than the north. The temperature sensor instrumentation cable was lightly coated with frost. The recent modification to drill more exhaust holes on the ends of the ducts was working satisfactorily and an even heating distribution was observed with the IR scanner. Visual and infrared observations of the GOX seals confirmed no leakage. No new pad debris concerns were noted.

OVERALL VIEW OF EXTERNAL TANK +Y+Z QUADRANT
ACREAGE FROST WAS PRESENT ON LH2 TANK



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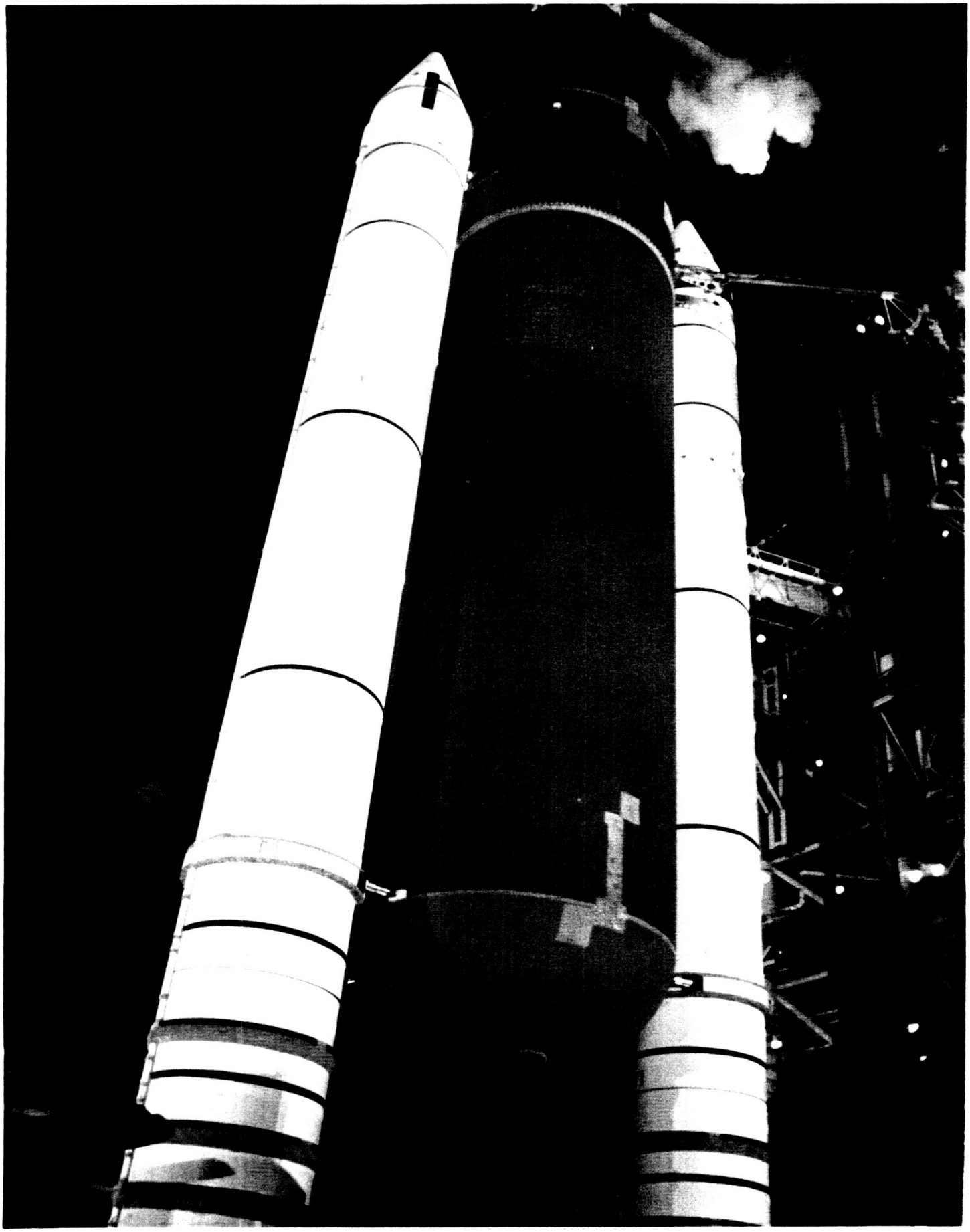
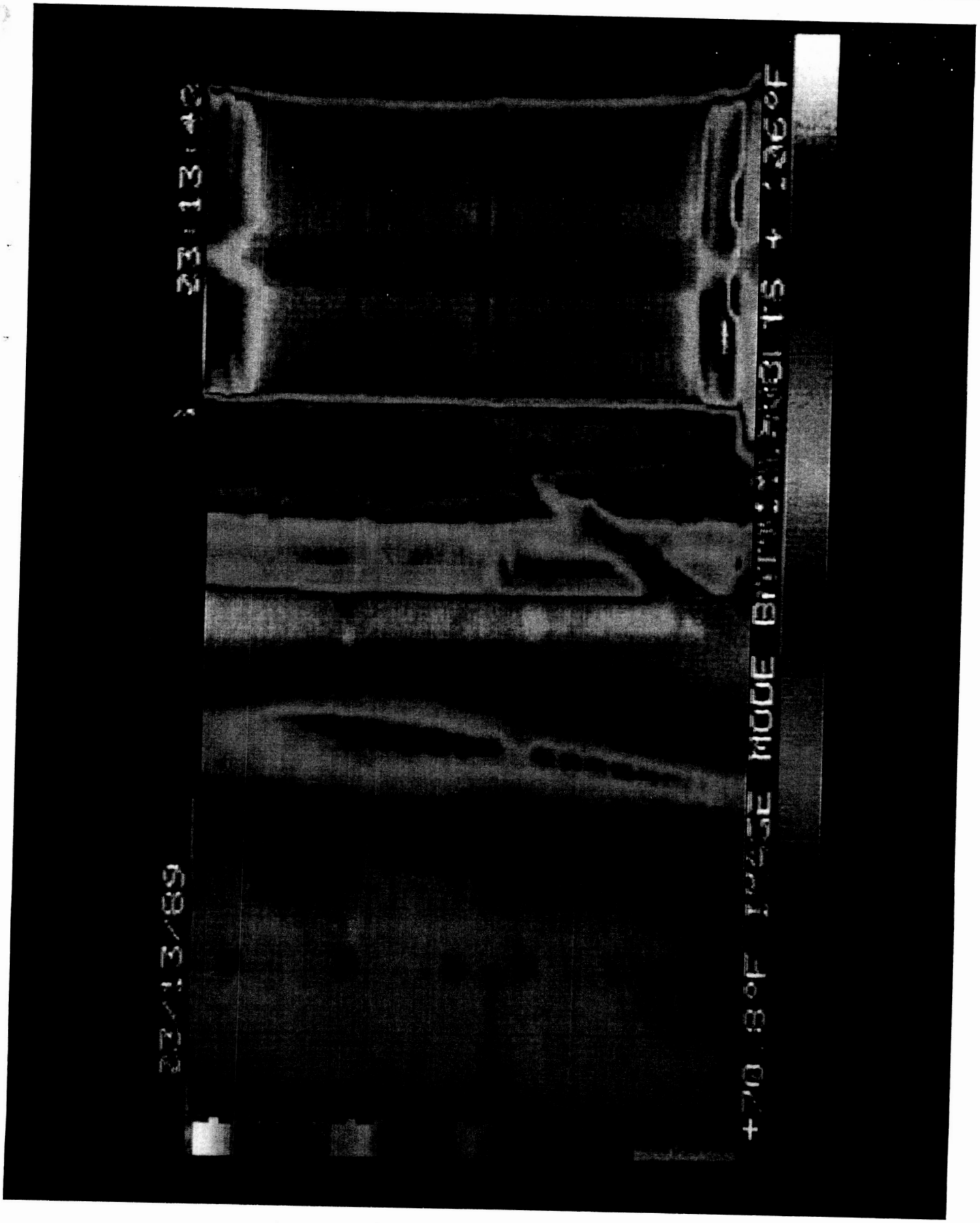
OVERALL VIEW OF EXTERNAL TANK -Y+Z QUADRANT
NO ACREAGE FROST HAD ACCUMULATED

ORIGINAL PAGE
COLOR PHOTOGRAPH



OVERALL VIEW OF EXTERNAL TANK -Z SIDE
ACREAGE FROST HAD ACCUMULATED ON LH2 TANK



SHUTTLE THERMAL IMAGE (STI) OF LH SRB JOINT HEATERS

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COLOR PHOTOGRAPH

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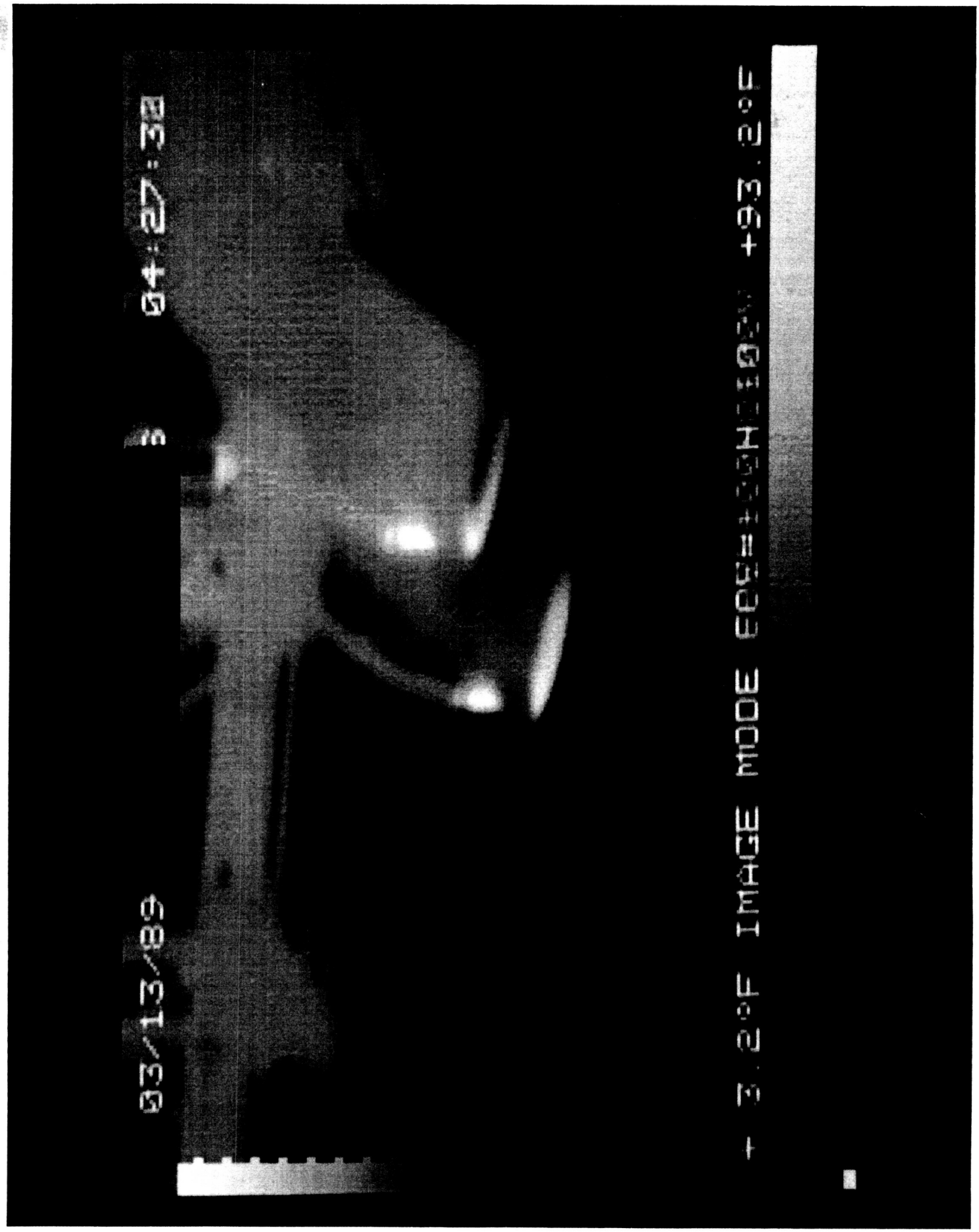
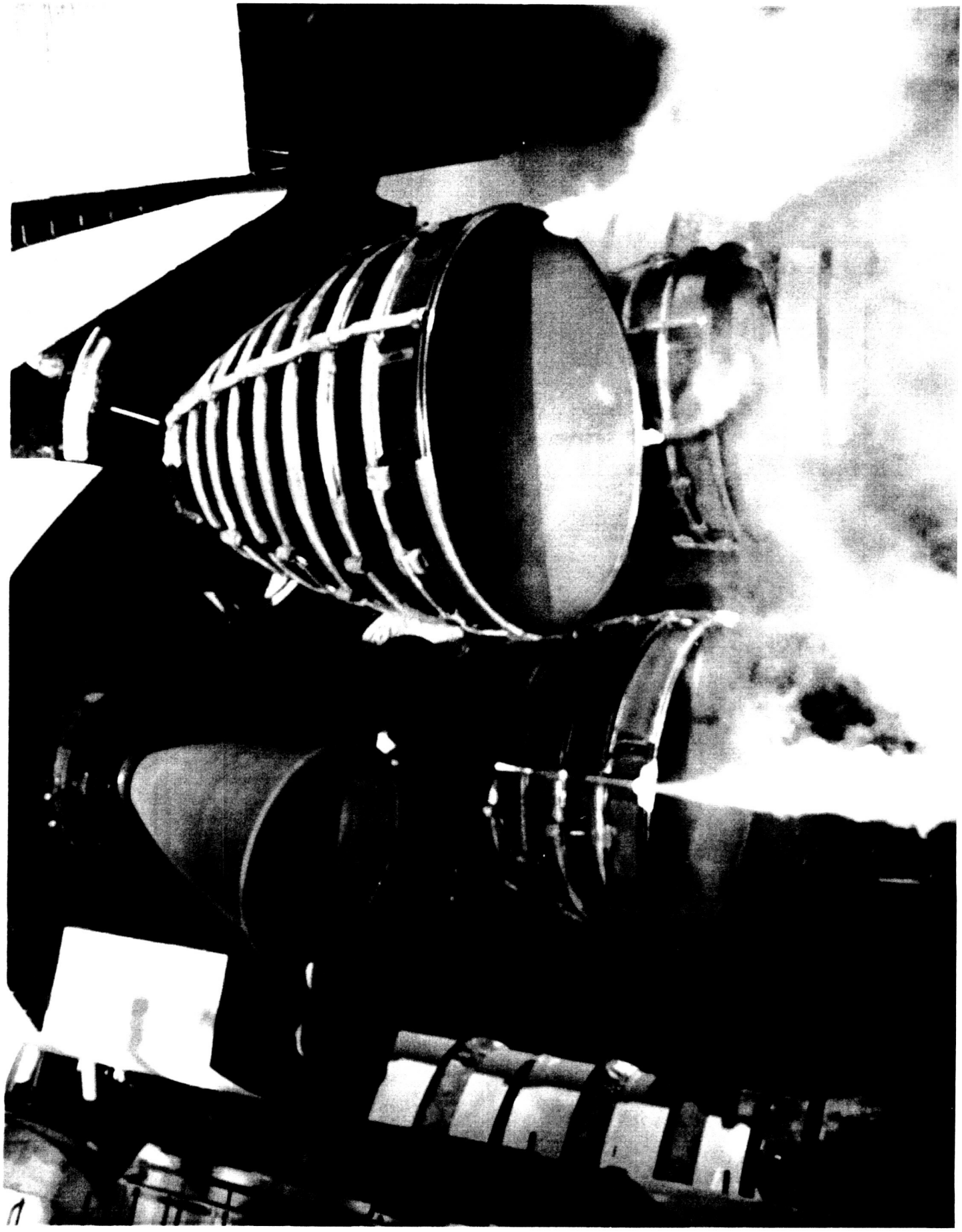
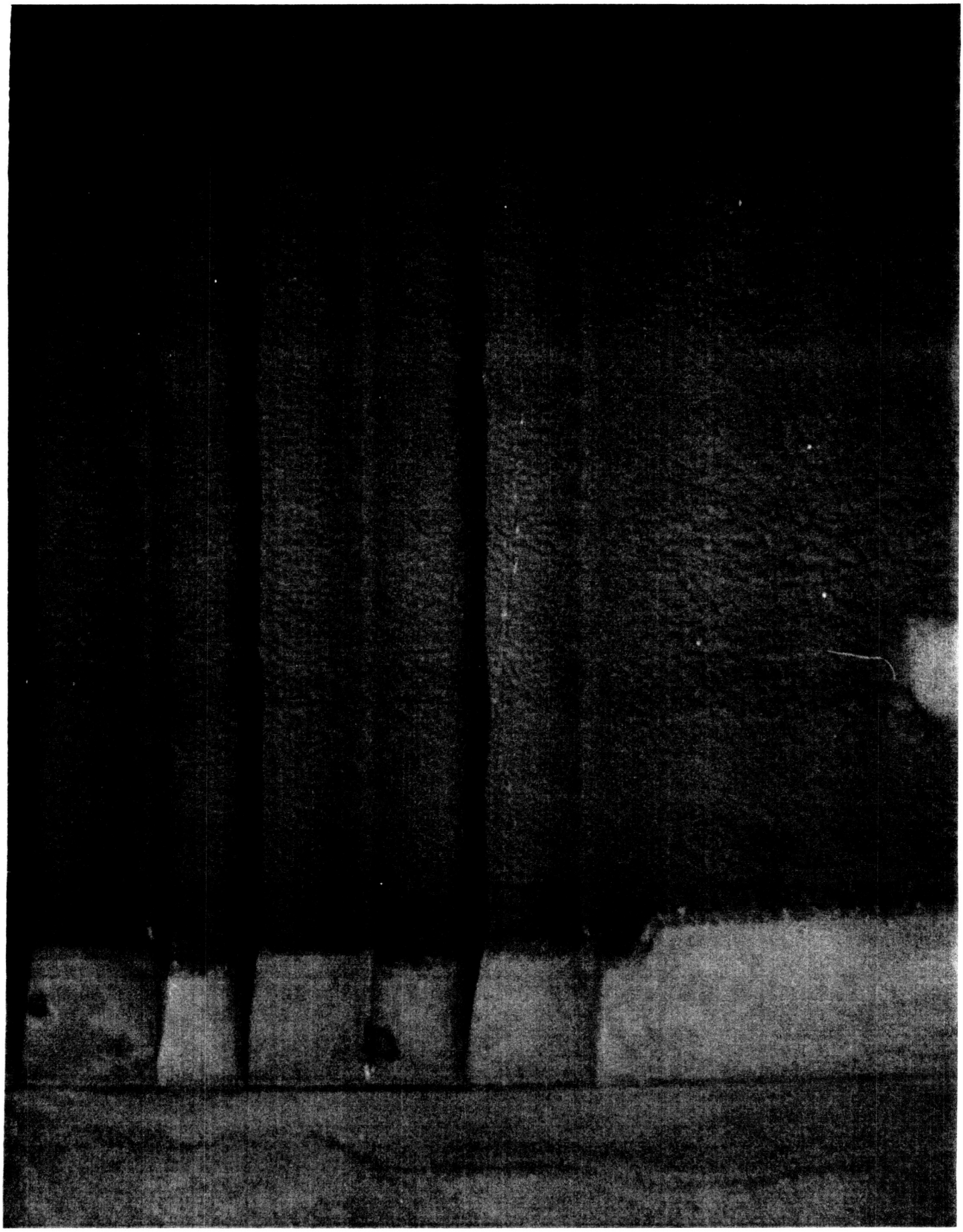


THERMAL IMAGE OF HEATED GOX VENT EXHAUST DUCTS. COLD SPOT ON SOUTH DUCT IS FROST-COVERED INSTRUMENTATION CABLE.

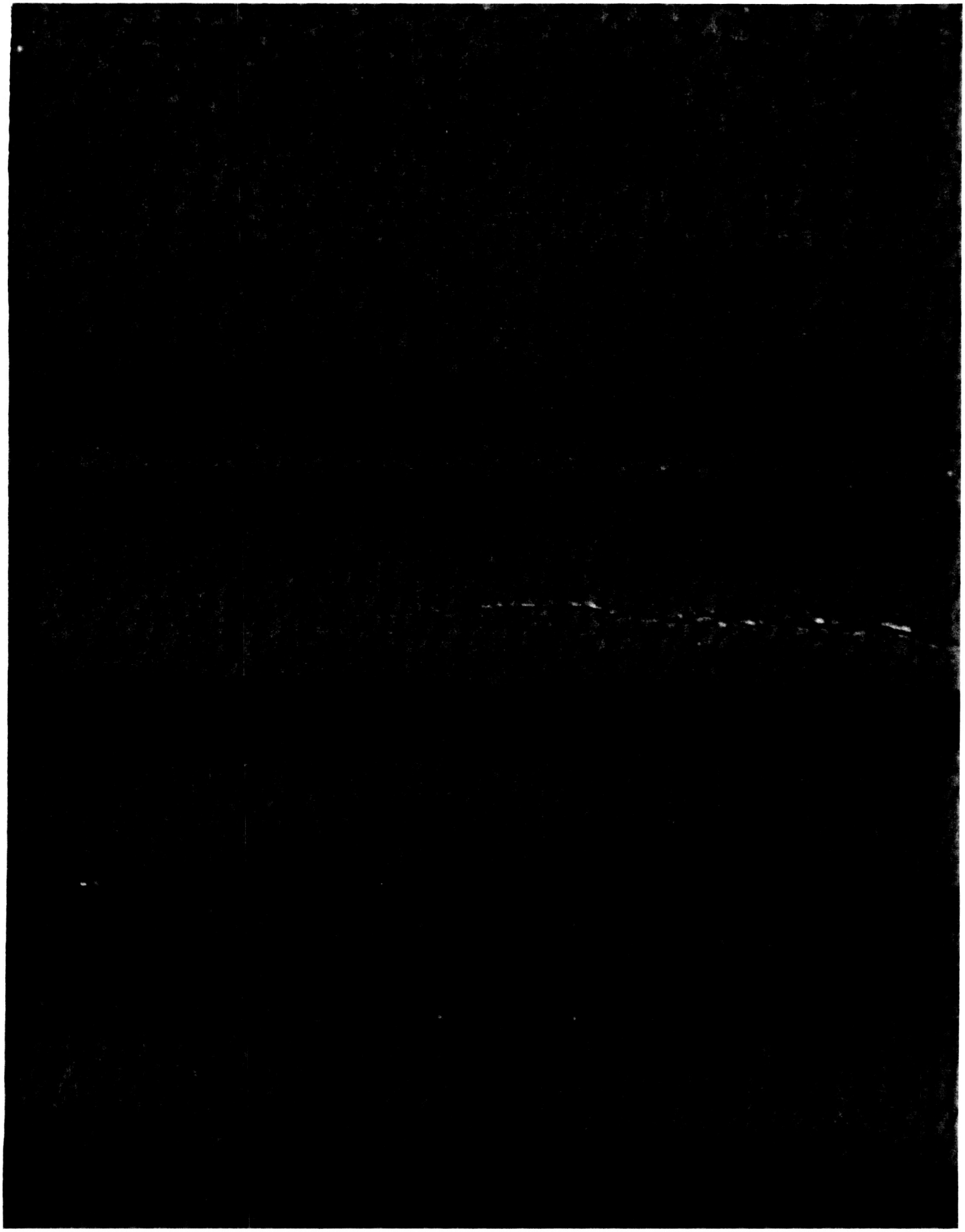


OVERALL VIEW OF SHUTTLE MAIN ENGINES. FROST HAS FORMED AT NOZZLE TO ENGINE MOUNTED HEATSHIELD INTERFACES

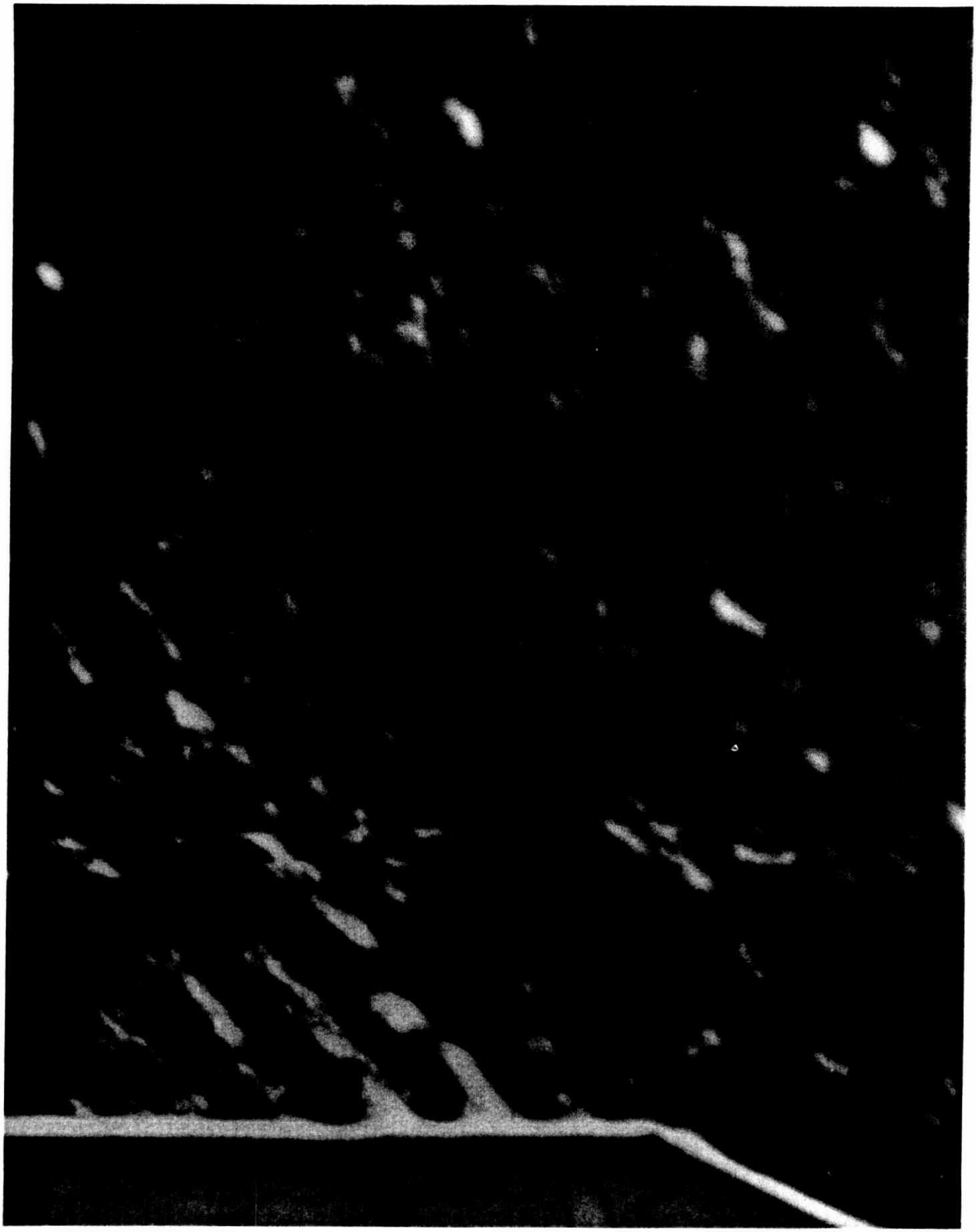
ICE/FROST ACCUMULATION ON SSME #2 ENGINE MOUNTED HEATSHIELD



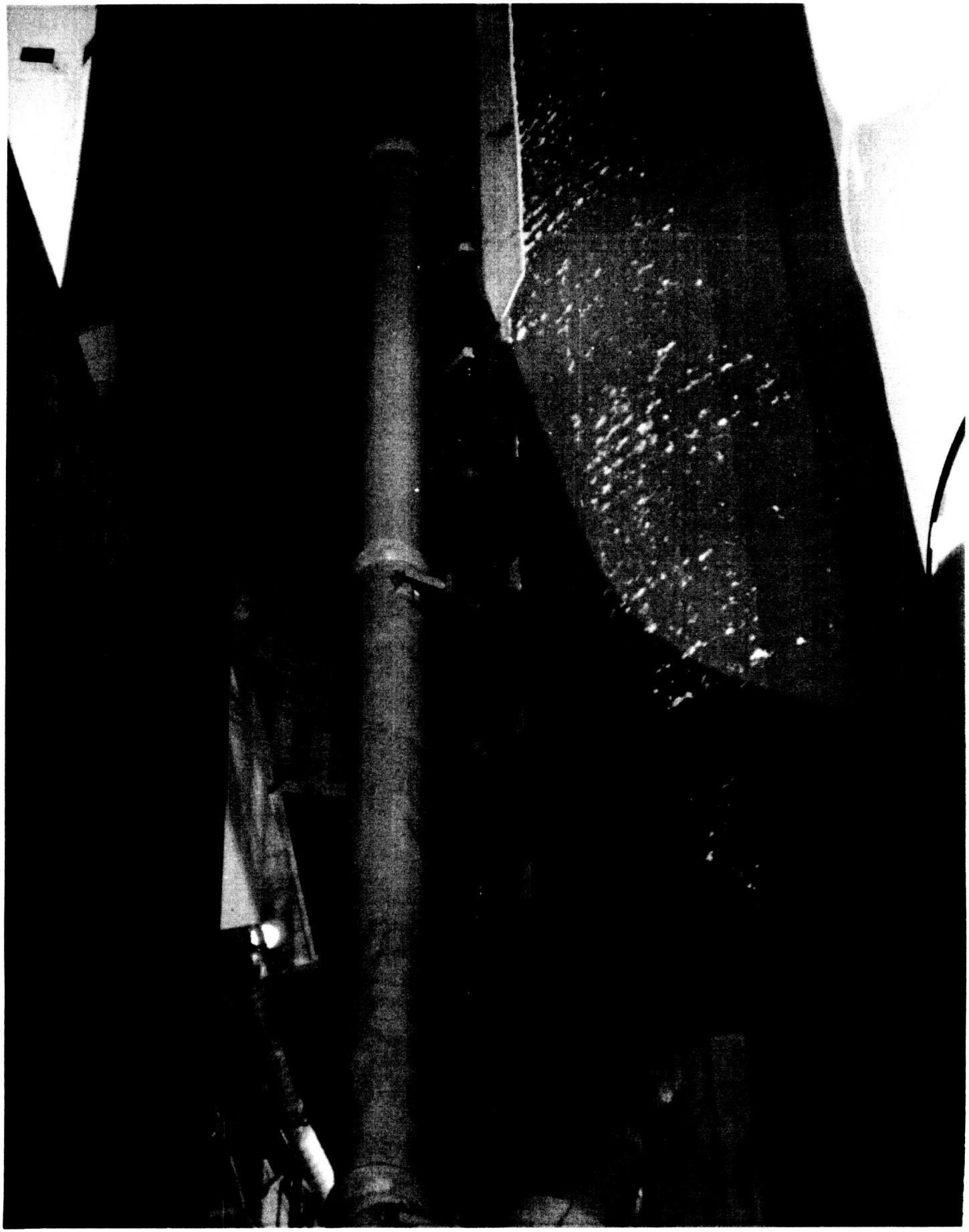
TWO FOOT LONGITUDINAL CRACK IN THE INTERTANK CPR
TPS AT THE LH2 TANK SPLICE NEAR THE -Y THRUST PANEL



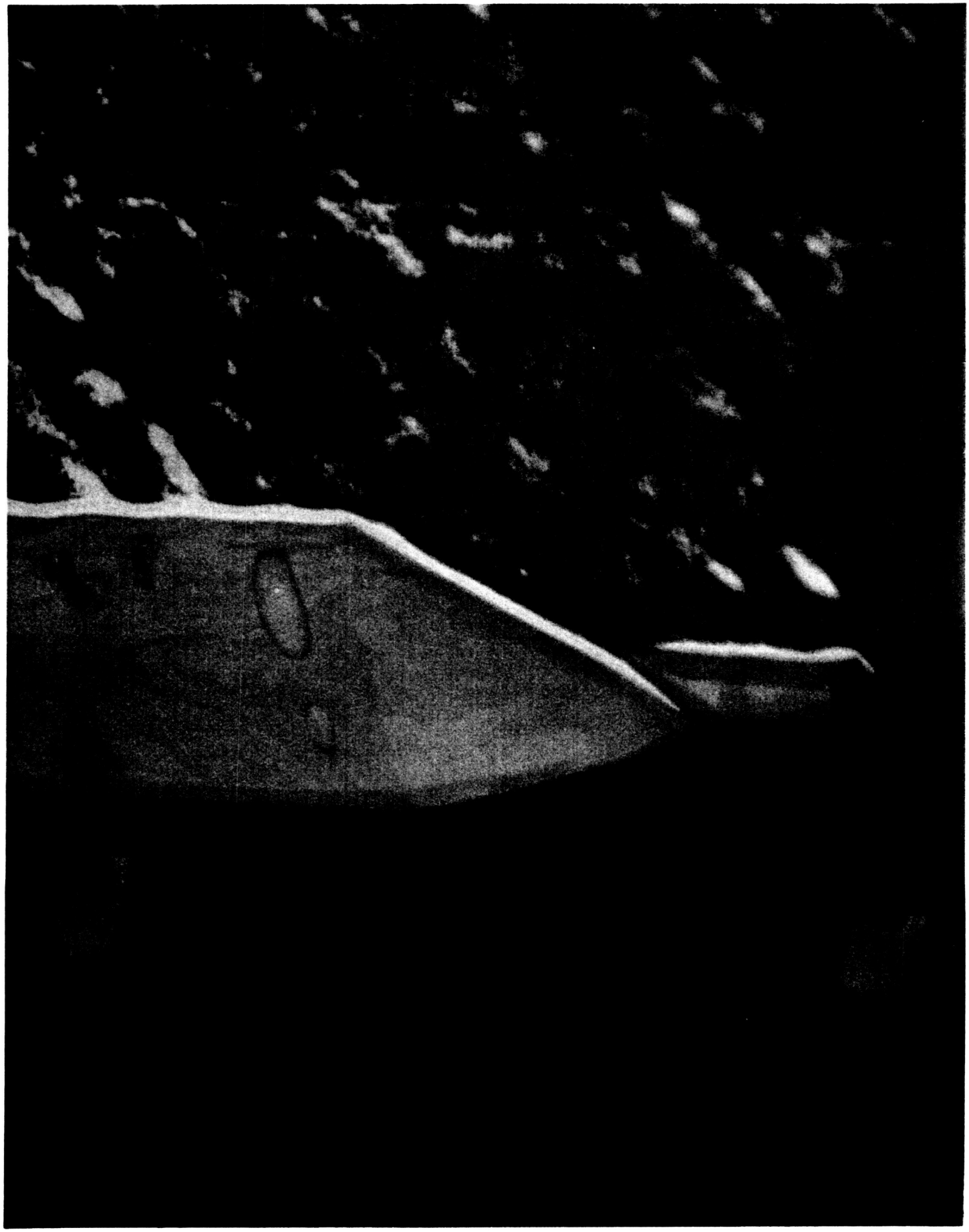
TWO FOOT CRACK IN INTERTANK CPR EXHIBITS NO OFFSET



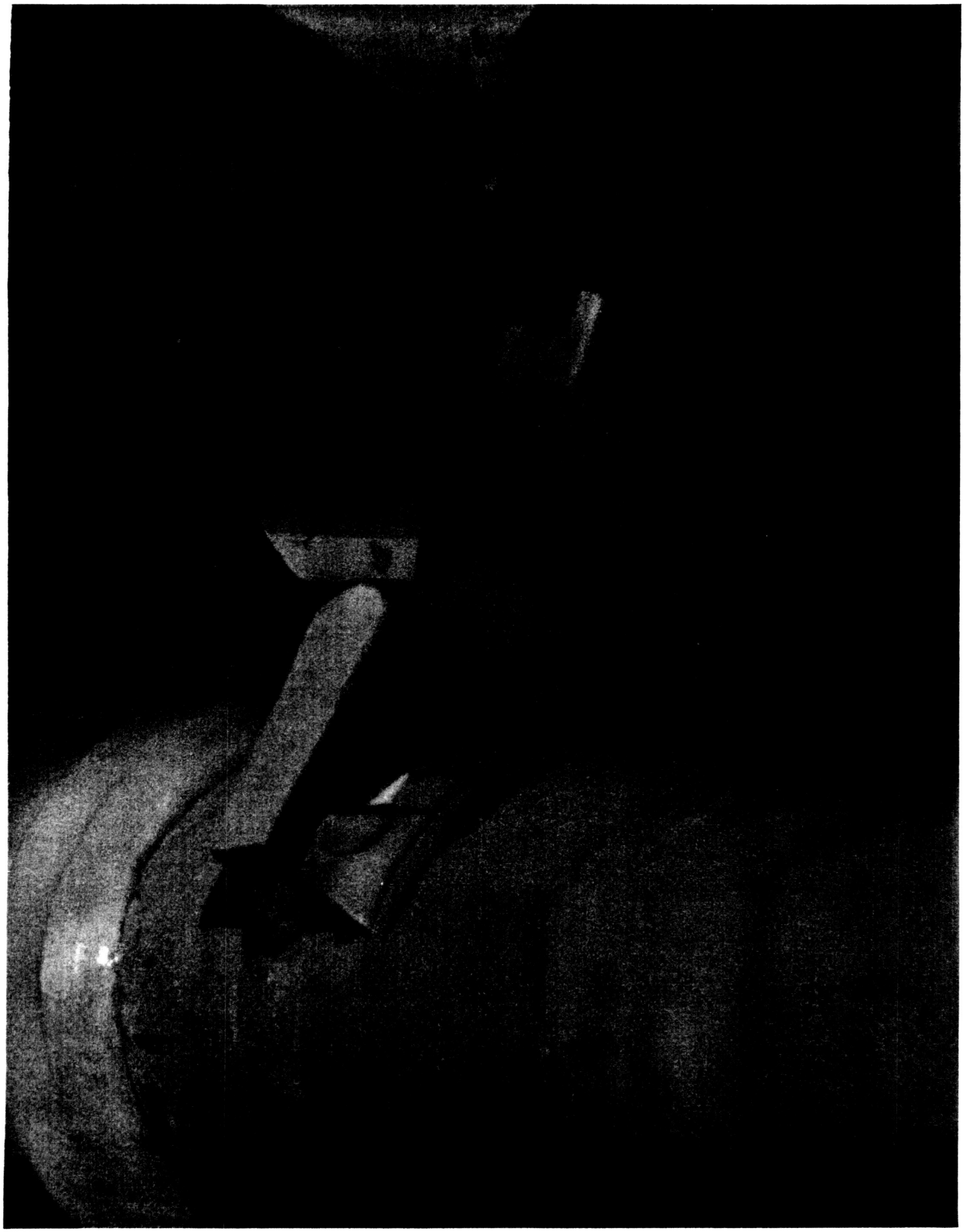
LH2 TANK ACREAGE FROST WAS ACCEPTABLE PER
THE NOMOGRAPHS AND NSTS-08303 CRITERIA



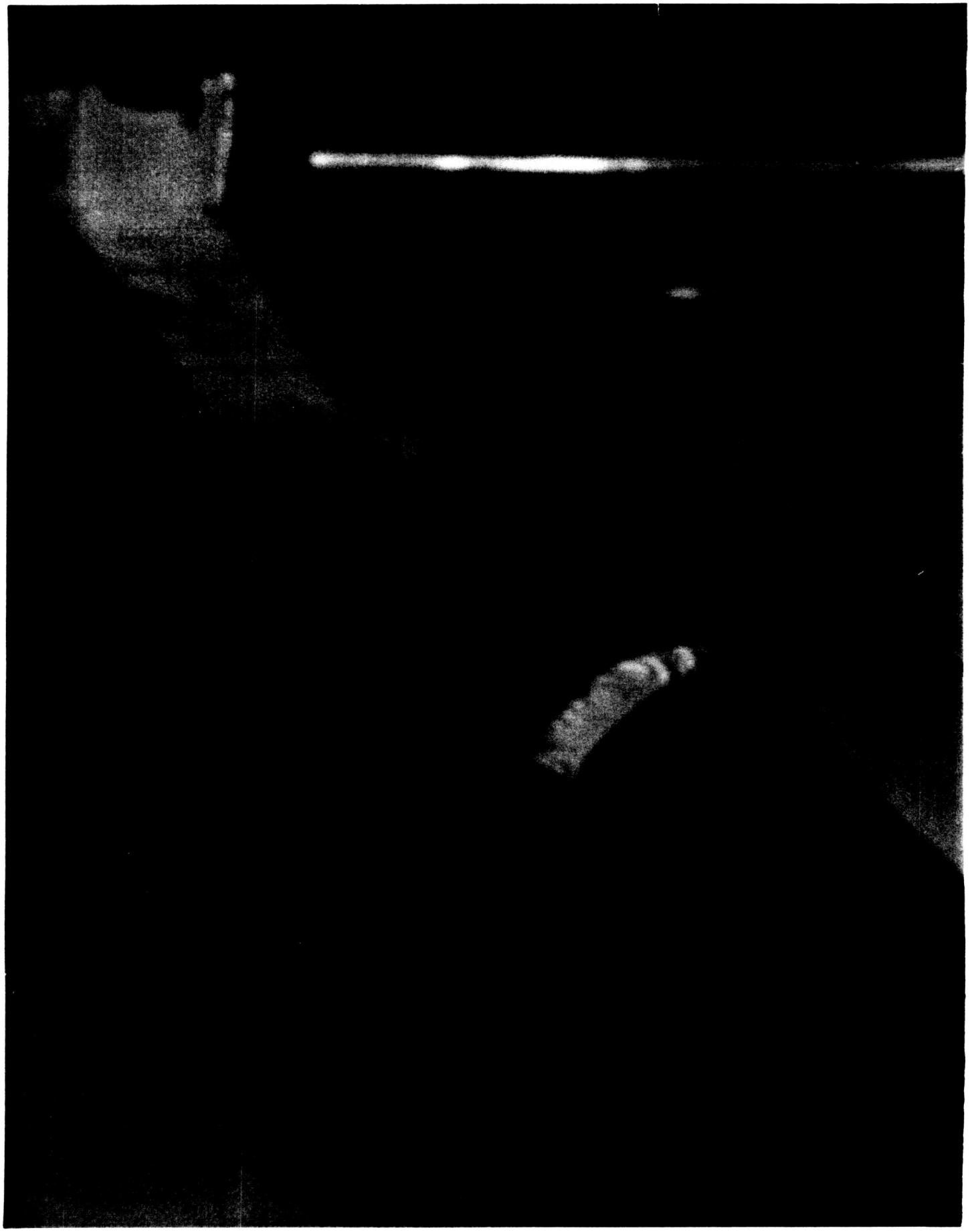
ACREAGE FROST ON LH2 TANK +Y+Z QUADRANT
HAD MELTED PRIOR TO LAUNCH



AN ICE/FROST LINE HAD FORMED ALONG THE PAL RAMP INTERFACE

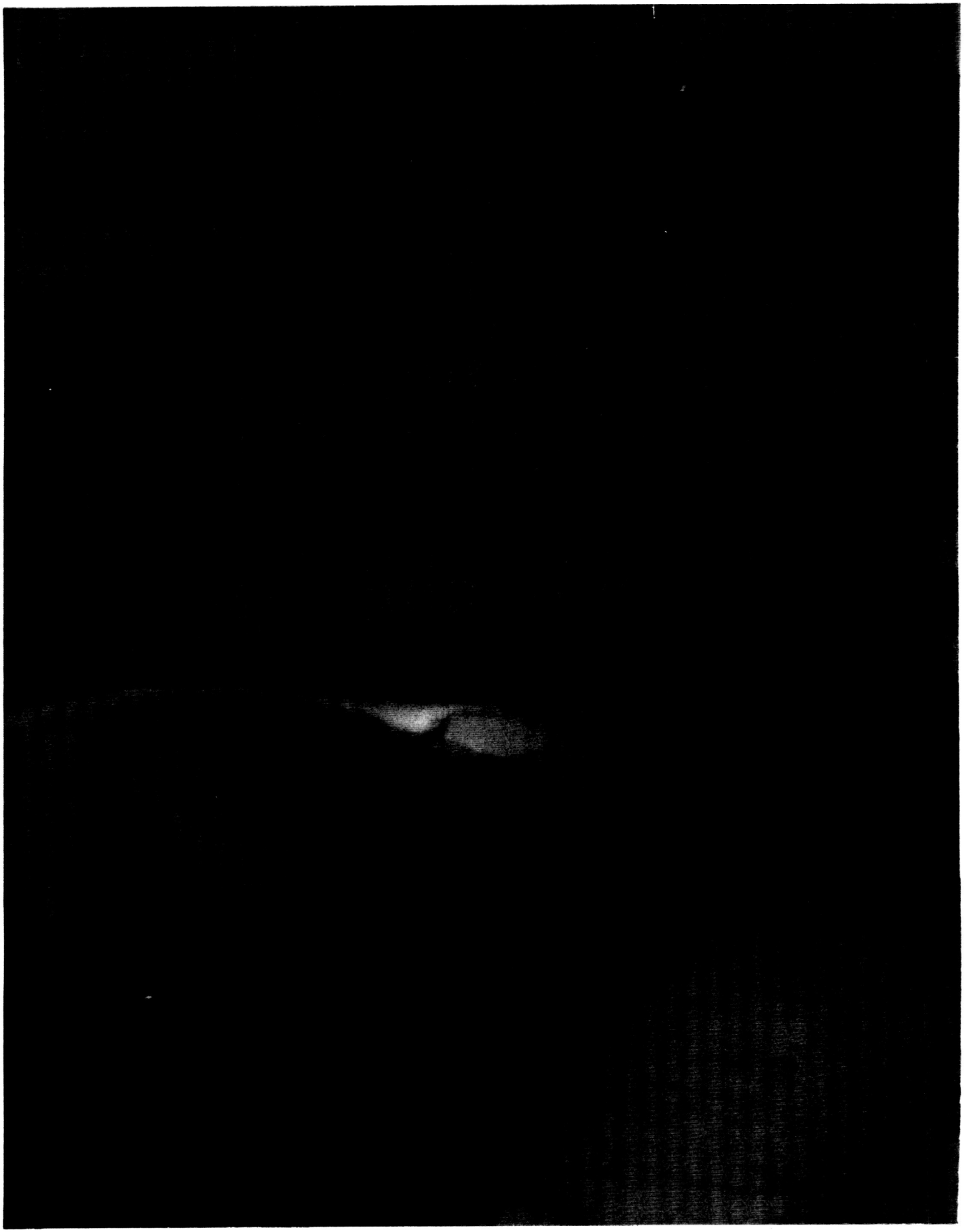


HARD ICE AND FROST HAD ACCUMULATED IN THE LO2 FEEDLINE SUPPORT BRACKETS



HARD ICE AND FROST HAD ACCUMULATED IN THE LO2 FEEDLINE BELLOWS STATION XT-1973

ORIGINAL PAGE
COLOR PHOTOGRAPH

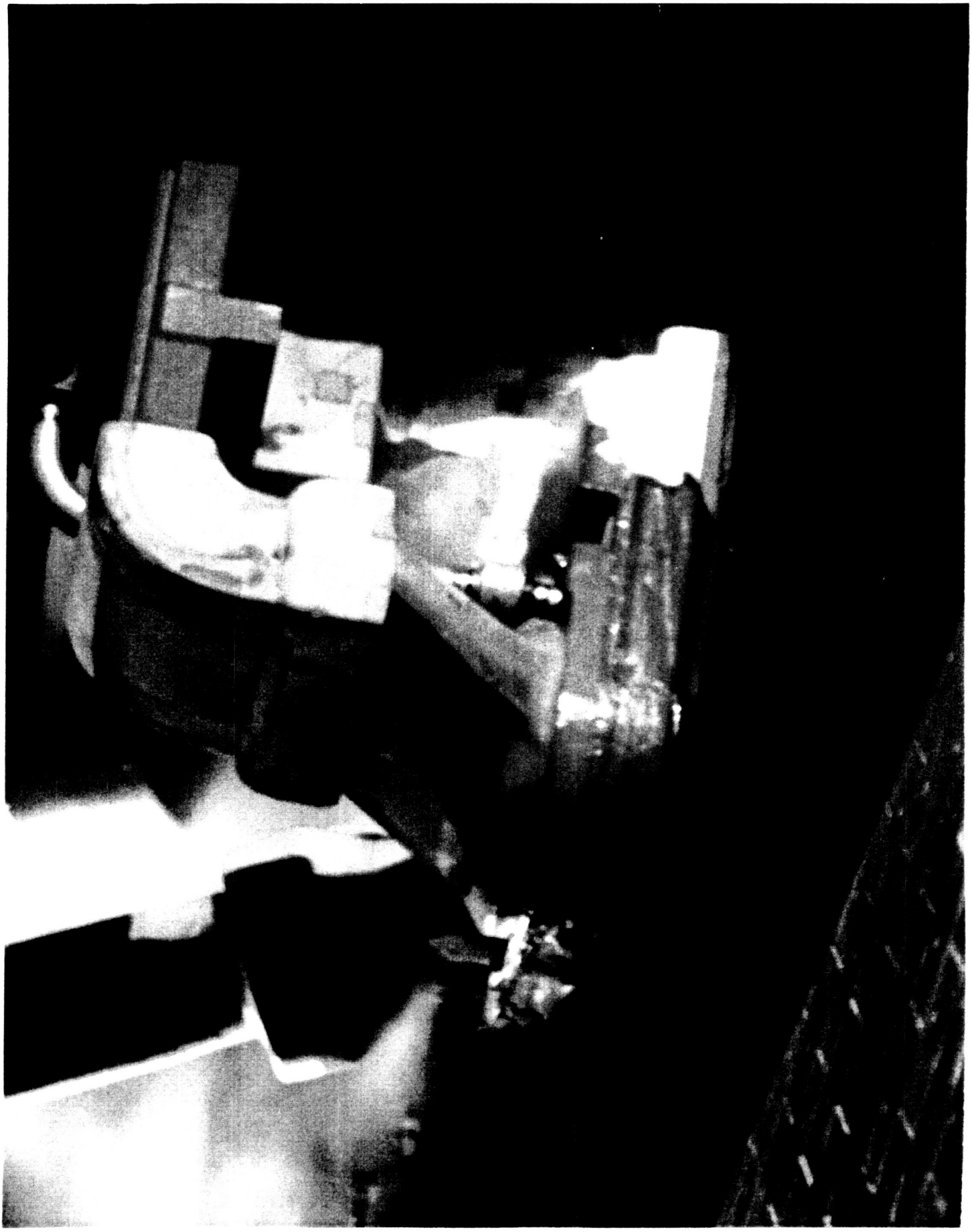


ICE/FROST HAD FORMED IN THE +Y THRUST STRUT TO ET INTERFACE

ICE/FROST ON LO2 UMBILICAL PURGE VENT
AND OUTBOARD FORWARD SIDE OF BAGGIE

ORIGINAL PAGE
COLOR PHOTOGRAPH

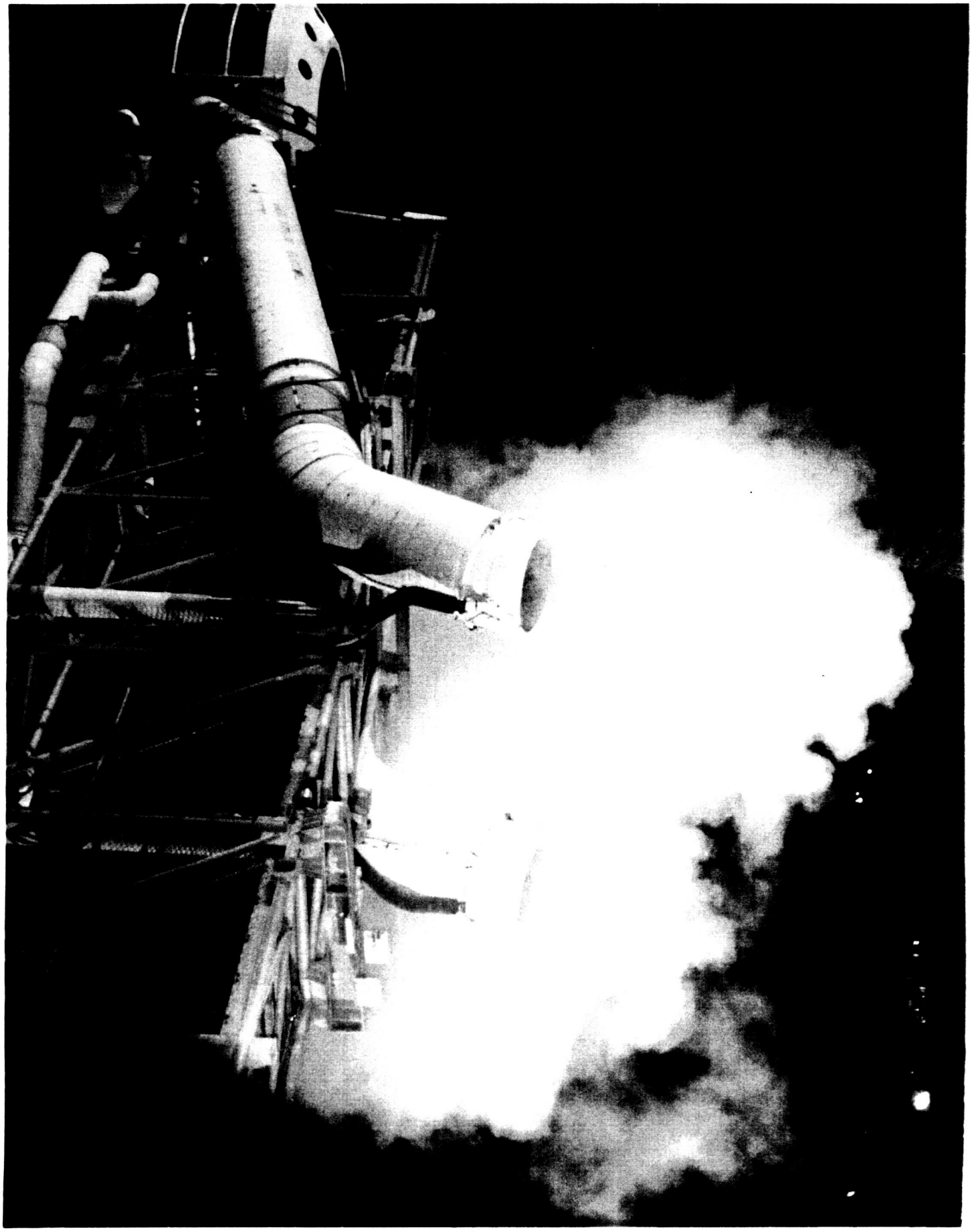
HEAVY ICE/FROST ACCUMULATION ON TOP AND OUTBOARD SIDE OF LH2 UMBILICAL. ICE/FROST ALONG FEEDLINE INTERFACE IS NOT TYPICAL



HEAVY ICE BUILD-UP ON THE LH2 UMBILICAL ACREAGE, IN THE CAVITIES, AND ALONG THE FEEDLINE-TO-UMBILICAL INTERFACE

HEAVY ICE BUILD-UP ON THE LH2 UMBILICAL ACREAGE, IN THE CAVITIES, AND ALONG THE FEEDLINE-TO-UMBILICAL INTERFACE

CONDENSATE DRIPS FROM AFT DOME. AN ICEBALL 1-INCH IN DIAMETER PROTRUDES FROM THE +Z SIDE OF MANHOLE COVER



ALMOST EVEN VENTING DISTRIBUTION OF GOX VAPORS
NO ICE/FROST FORMATION ON GOX VENT EXHAUST DUCTS

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the pad and surrounding area was conducted on 13 March, 1989 from launch + 1.5 to 3.5 hours. The MLP, FSS, pad apron, and acreage areas were inspected, except for the flame trench and areas north to the perimeter fence which were restricted due to high concentrations of HCL. This area was inspected when the HCL levels subsided the following day. No significant flight hardware or TPS materials were found with the exception of three small portions of Q-felt plug (two 1/2-inch diameter and one 1-inch diameter). Many of these plugs have been recovered on previous post launch debris inspections. The usual SRB throat plug material (foam and RTV) was found. Water trough material from the SRB exhaust holes was scattered throughout the field and on the pad apron.

SRB holddown post erosion was negligible for this launch. South holddown post shim material was intact, but had debonded from the shoe sidewall on holddown post #6. No NSI or frangible nut fragments were found during the walkdown. However, a piece of frangible nut and one NSI cartridge fragment were recovered inside HDP #8 during stud removal per OMI B5032. All of the doghouse blast covers on the north holddown posts were in the closed position, exhibited no apparent damage, and did not appear to be missing any parts. The SRB aft skirt purge lines were in place and exhibited minimal damage. The SRB joint heater umbilicals showed no excessive damage after separation. Handrail posts had been eroded by the SRB plume and will be inspected for material damage prior to reinstallation of the handrails.

Several pieces of typical facility debris were found at the pad perimeter. Two metal electrical receptacle covers and a terminal box door for a MLP/Portable Purge Unit (PPU) interface on the northwest corner of the MLP were missing. Two emergency egress slidewire baskets were released after the vehicle cleared the tower. The other five baskets were still positioned on the FSS 195 foot level and exhibited no launch damage.

The TSM's, Orbiter access arm, and GOX vent arm showed minimal launch damage. The GH2 vent arm was latched on the third tooth of the latching mechanism. No loose cables dangled from the haunch.

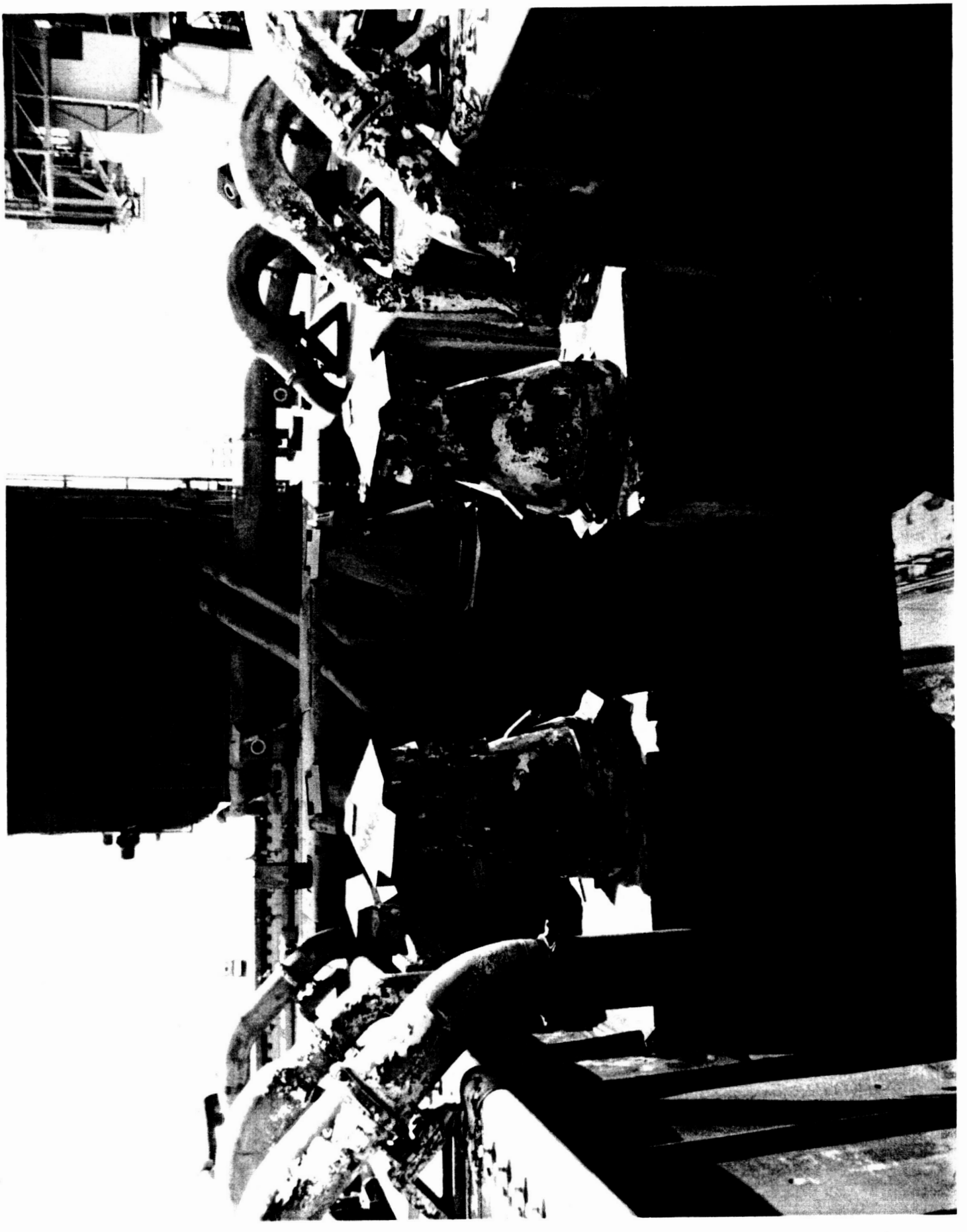
The Shuttle Thermal Imager (STI) units located at Camera Site 2 and on the roof of the RSS sustained no launch damage and were operational after launch. Both housings were coated with SRB residue.

Overall, there was very little damage to the launch pad.

Patrick AFB and MILA tracking radars had been recalibrated for increased sensitivity during the launch of STS-29R. Although the signals were very weak, 40 objects were detected in the

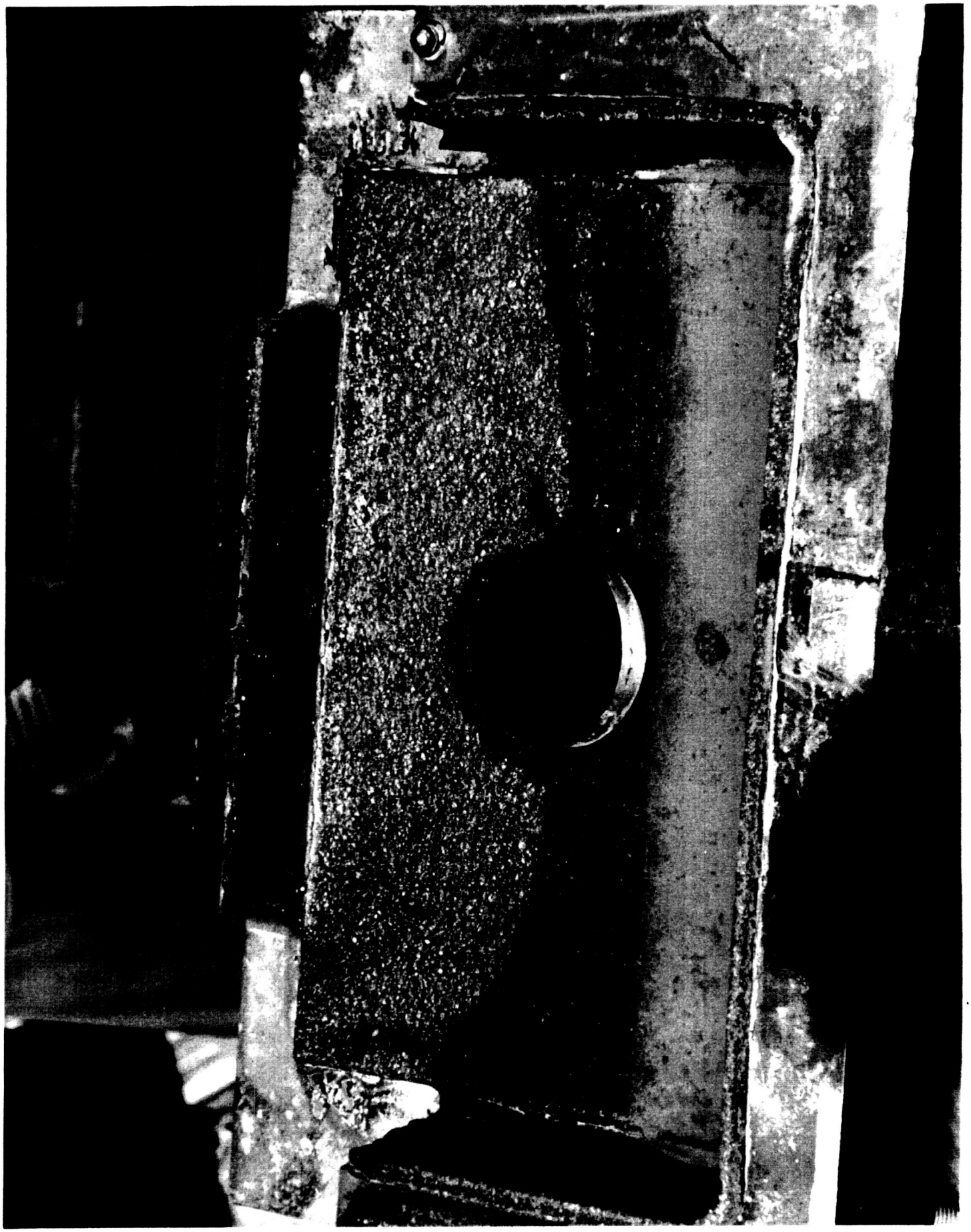
time frame T+140 thru 258 seconds, well after SRB separation. Fourteen of the objects were detected by two radars and only 3 objects were imaged by all three radars. The radar data cannot provide specific object characteristics, such as size and material type.

The debris inspection continued on 3/14/89 and was expanded to include areas outside the pad perimeter fence. Ground teams searched the beach, railroad tracks, and beach road from the northern KSC boundary to the Titan complex. The NASA helicopter was utilized to cover the water areas around the pad, the beach from the Cape lighthouse to a point 10 miles north of the pad, and ocean area under the flight path. No additional flight hardware was found.



OVERALL VIEW OF LH SRB HOLDDOWN POSTS AFTER LAUNCH

ORIGINAL PAGE
COLOR PHOTOGRAPH



TYPICAL CONDITION OF SOUTH HOLDDOWN POST SHIM/SIDEWALL MATERIAL AFTER LAUNCH

MISSING COVERS FROM MLP/PORTABLE PURGE UNIT INTERFACE TERMINAL BOX AND ELECTRICAL RECEPTACLES

6.0 LAUNCH FILM SUMMARY/PROBLEM REPORT DISPOSITION

A total of 146 film and video data items, which included 49 videos, 59 16mm films, 30 35mm films, 6 70mm films, and 2 special films were reviewed starting on Launch day.

No major vehicle damage or lost flight hardware was observed that would have affected the mission. However, some tiles on the base heat shield and RCS stingers were chipped by SSME acoustics (E-17, 19, 23, 24). One Q-felt plug from the SSME #1 region is briefly visible (E-24). Six tile gap fillers are shaken loose by SSME ignition and originate from the -Z side of the SSME #1 engine mounted heat shield (E-19, 23).

Material in an area of sunlight reflection on the External Tank station XT-371, half way between the fairing and the louver, appears raised and moves with SSME ignition - may be delaminated topcoat. A small piece of frost or SLA just below the louver's edge comes loose at T-0 and is blown south (OTV 161).

Just prior to and during SSME ignition dense vapors emanate from the ET/ORB LH2 umbilical. Cryogenic liquid drops, with vapor trails, fall as far as the aft edge of the body flap before vaporizing completely. The vapors continue to envelope the umbilical through early ascent and tower clear (E-6, 26, 31, 34, 35, 36, 40, 52, 59, 61, 65, 79, OTV 109, OTV 154, OTV 163).

A shower of ice and frost particles from the ET/ORB LH2 and LO2 umbilicals falls past the body flap during SSME ignition, but no Orbiter tile damage is visible (E-17, 19, 23, 25, 26, 31, and OTV 154).

Holddown post #5 stud frangible nut ordnance fires and flash is visible through blast container vent holes (E-12, EX4). Frangible nut and NSI cartridge fragments continue to be lost from the holddown post debris containers. Two NSI pieces fall from the aft skirt HDP #8 stud hole as the vehicle rises (E-14). Three large and numerous smaller pieces of instafoam break loose from the aft skirt adjacent to the holddown post shoes (E-10, 11, 27). SRB thermal curtain tape is loose (E-2, 8, 9, 10, 15, 27, 28, EX1, EX4).

Small pieces of ET TPS are pulled loose from the right side of the GUCP plate cutout as the GUCP disconnects at T-0 (E-33).

Many film and video items record various amounts of flying debris. This debris is SRB throat plug material and shredded water troughs - an expected occurrence.

Numerous pieces of debris from the vehicle are visible during ascent. Most have been identified as ice/frost particles from the ET/ORB umbilicals, Orbiter RCS paper covers, instafoam particles from the SRB aft skirt, and pieces of TPS from the ET intertank area (E-52, 53, 63, 202, 213, 217, 220, 222, 425).

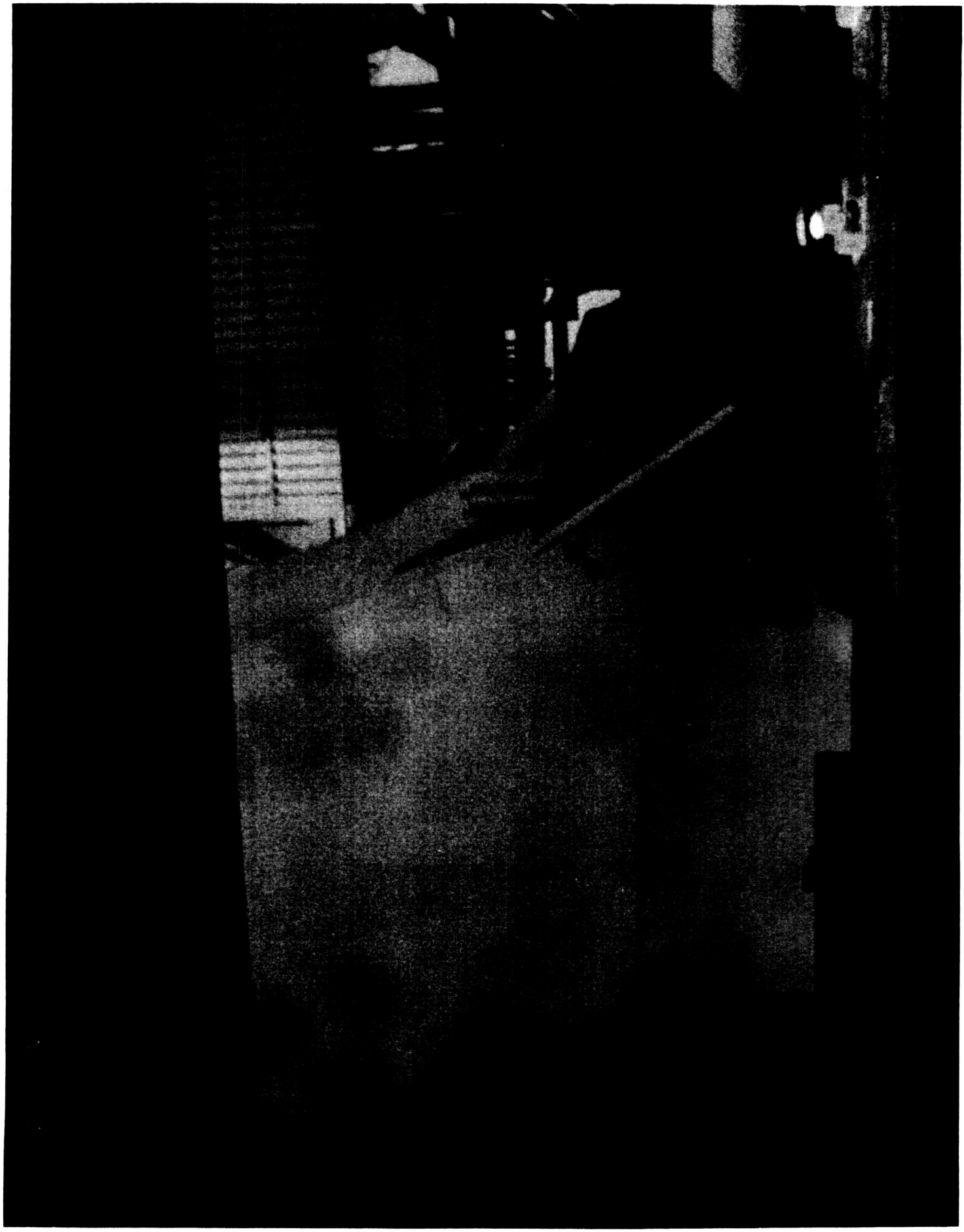
At T+61 seconds, an event is visible on the -Z side of the ET. A shower of particles or puff of vapor originates near the intertank area, possibly the GUCP or LH2 tank flange, and follows the aerodynamic streamlines aft until it expands/dissipates near the 2058 ring. The event is most likely the breakup of a piece of TPS from a divot in the intertank area, but could also be ice/frost from the GUCP or SLA 220 from the LH SRB -Z RSS antenna ramp (E-207, 211, 220).

Hand-held still photography of the ET taken by the crew just after separation revealed a 6-inch divot on the +Y longeron where a previous vendor repair existed. Five divots ranging in size from 14 to 20 inches in diameter are visible in the -Y thrust panel and along the intertank-to-LH2 tank flange/acreage ramp. Numerous smaller divots were present along both LH2 and LO2 tank to intertank flanges. In addition, the bipods did not fold up against the tank as designed.

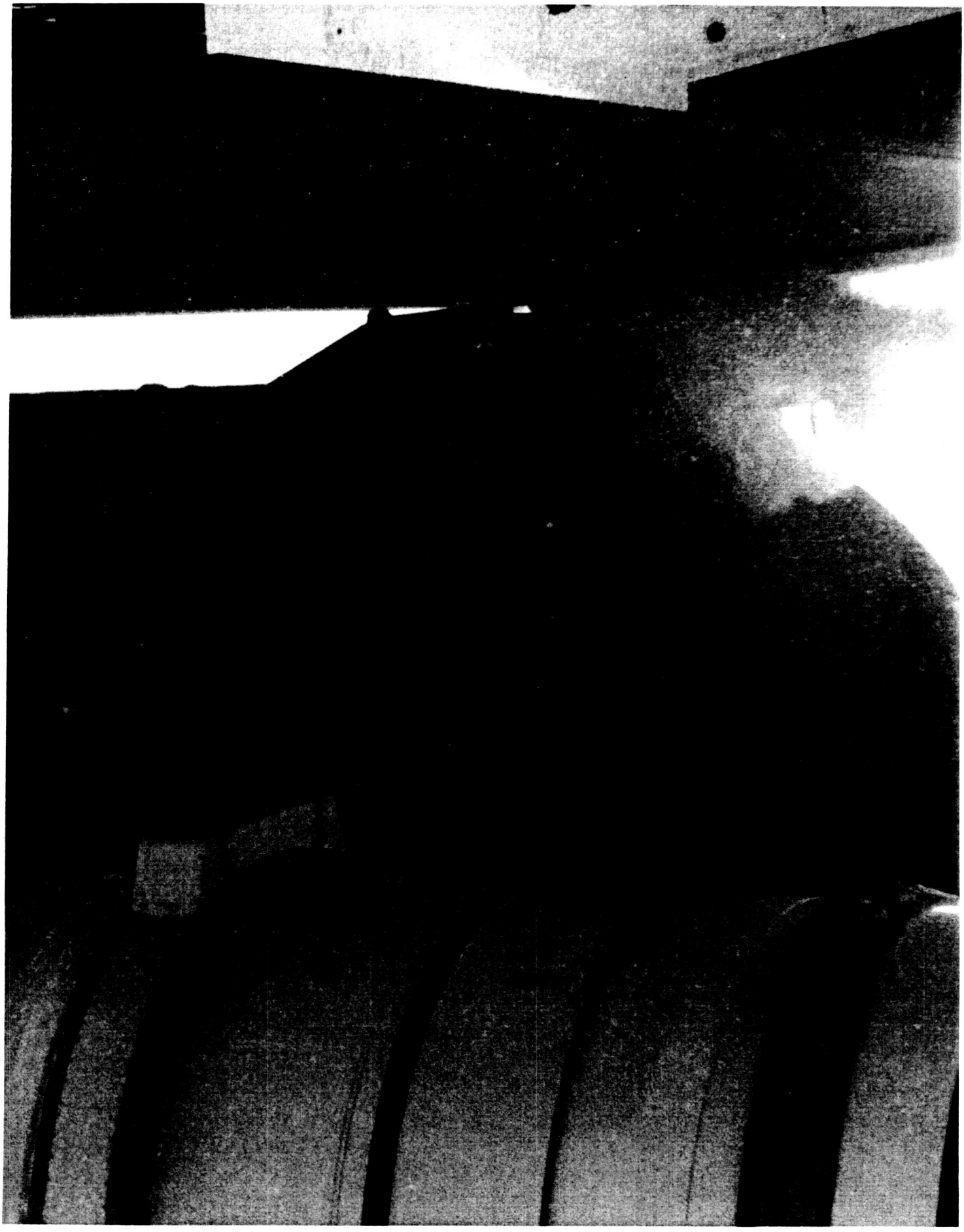
There were no major facility anomalies. No swing arms or other pad structures contacted the vehicle during liftoff. Two MLP/ Portable Purge Unit (PPU) electrical box covers from the northwest corner of the MLP deck were blown outward away from the vehicle in a northwesterly direction about 500 feet at 14:57:03.911 and 14:57:04.155, respectively (E-60, 61). The two emergency egress slidewire baskets found after launch in the landing zone did not release from the FSS 195 foot level during the time period from SSME ignition through tower clear (E-60, 64).

No PR's or IPR's were generated as a result of the launch film and video data review. Observed Post Launch Anomalies are listed in Section 10.0.

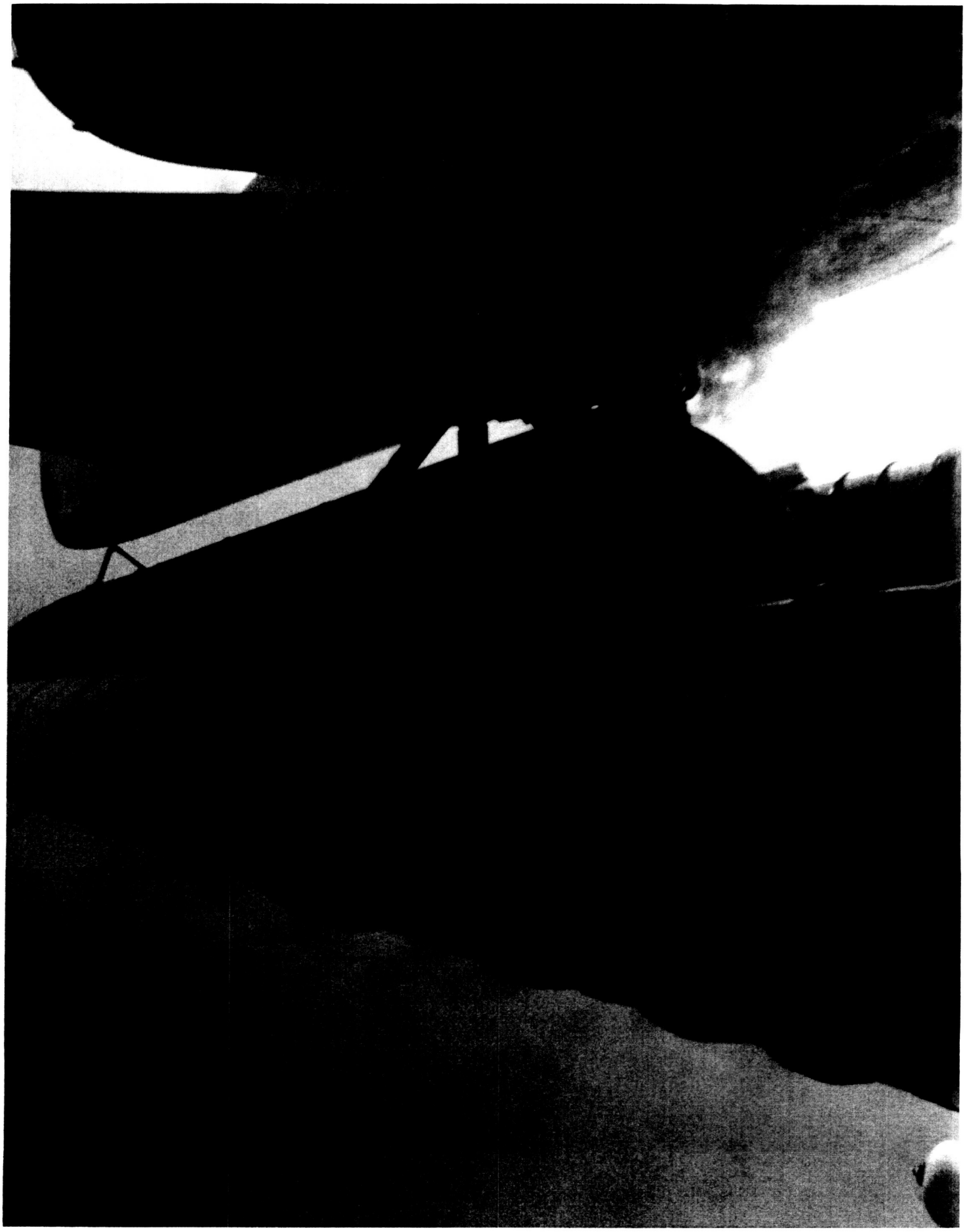
TWO NSI CARTRIDGE FRAGMENTS FALL FROM THE AFT SKIRT HDP #8 STUD HOLE AS THE VEHICLE RISES



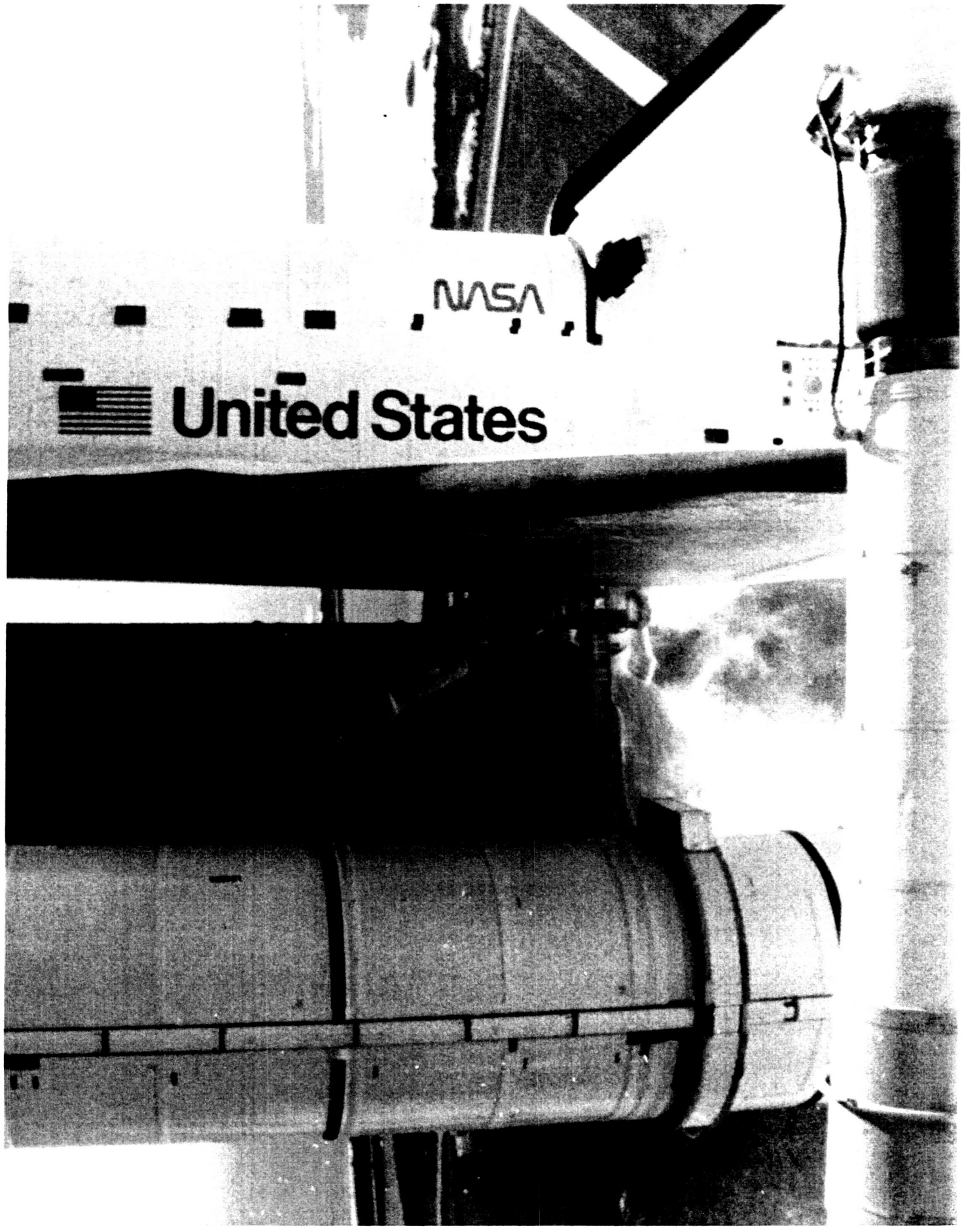
THREE LARGE PIECES OF INSTAFOAM BREAK LOOSE FROM THE AFT SKIRT ADJACENT TO THE HOLDDOWN POST SHOE



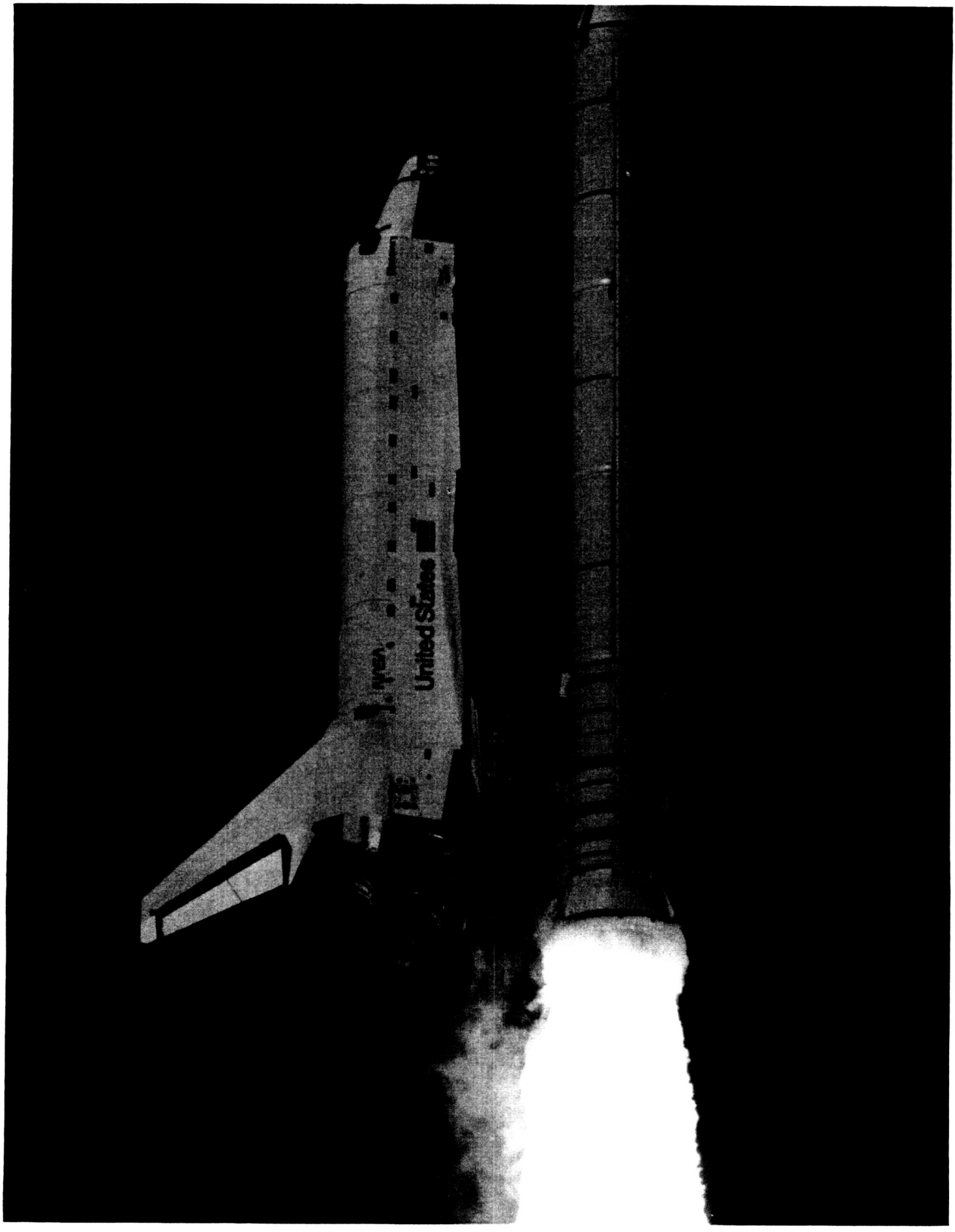
JUST PRIOR TO AND DURING SSME IGNITION, DENSE VAPORS EMANATE FROM THE ET/ORB LH2 UMBILICAL



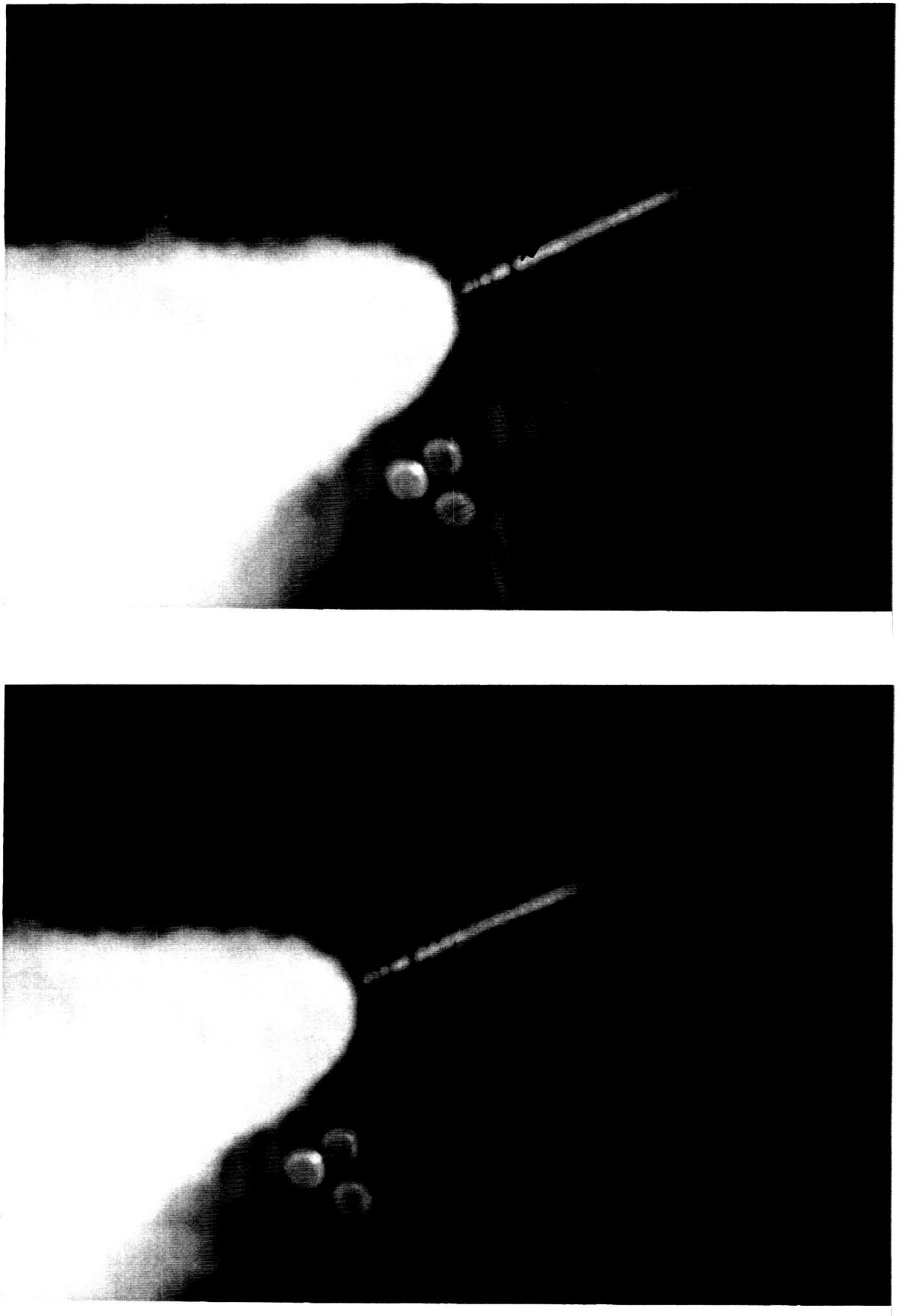
CRYOGENIC LIQUID DROPS, WITH VAPOR TRAILS, FALL AS FAR AS THE AFT EDGE OF THE BODY FLAP BEFORE VAPORIZING COMPLETELY



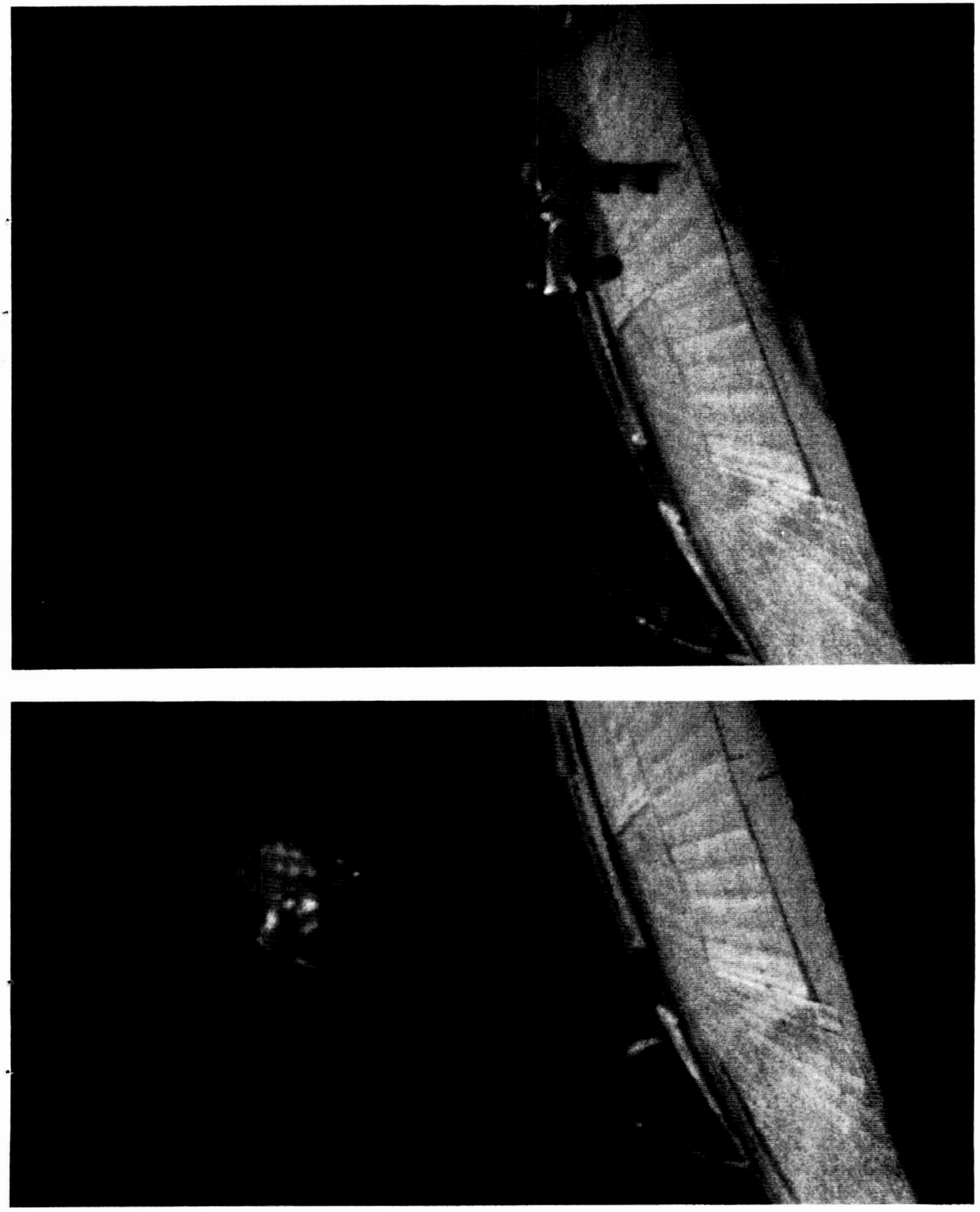
THE VAPORS CONTINUE TO ENVELOPE THE ET/ORB LH2 UMBILICAL THROUGH EARLY ASCENT AND TOWER CLEAR



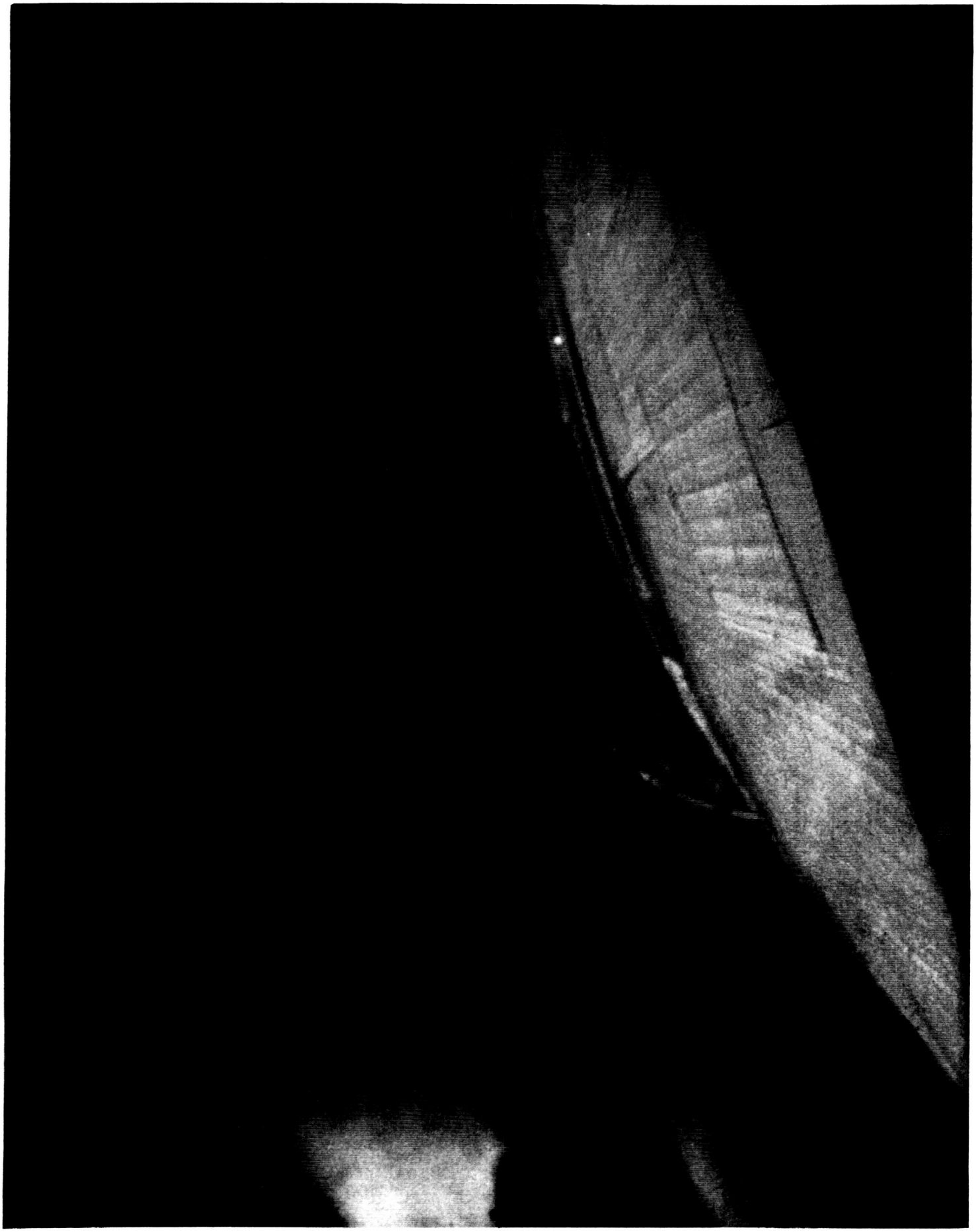
SOME VAPOR STILL OBSCURES ET/ORB LH2 UMBILICAL JUST AFTER TOWER CLEAR. NOTE ICE FROM UMBILICALS FALLING PAST ORBITER BODY FLAP



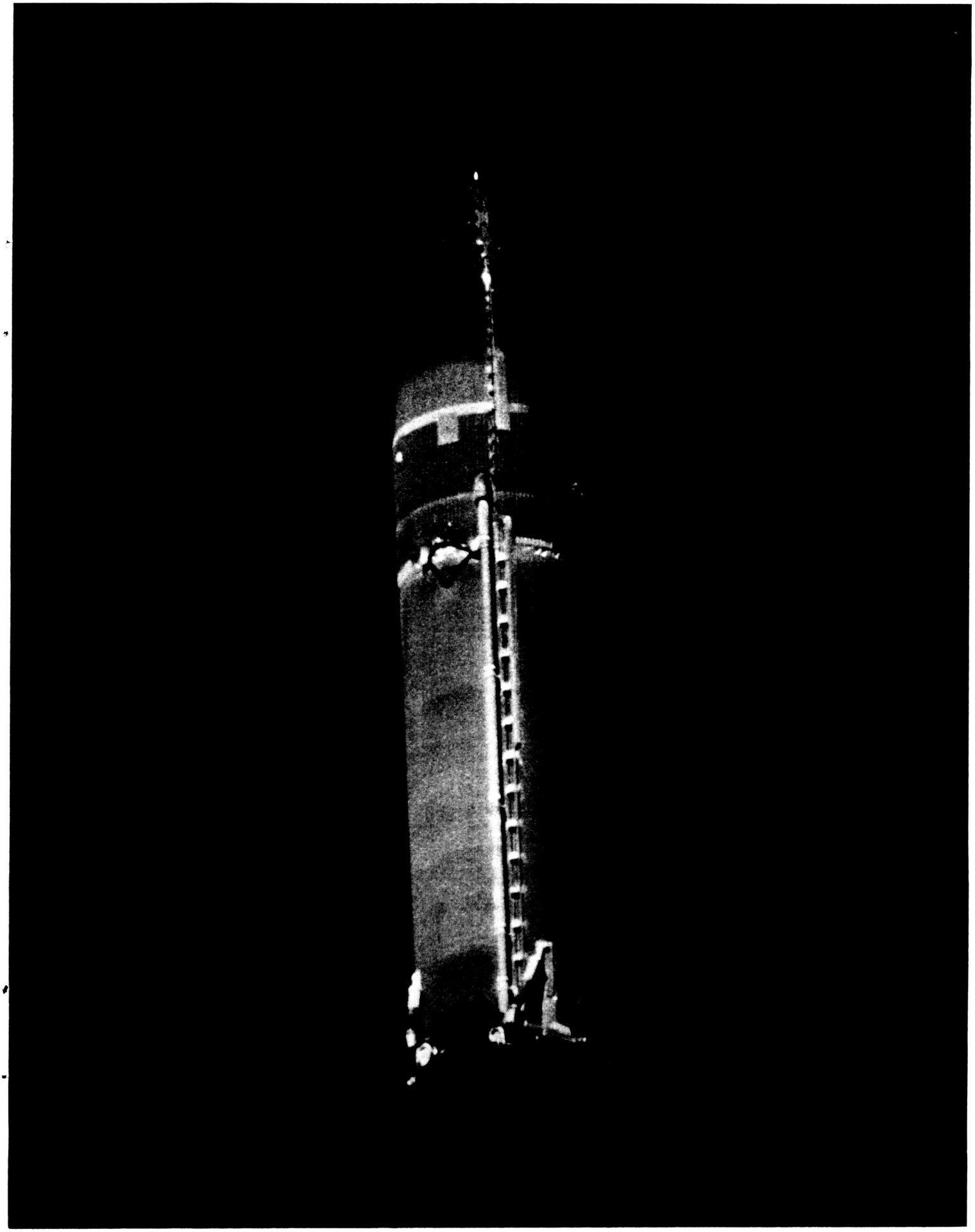
EVENT AT T+61 SECONDS MAY BE A PIECE OF TPS FROM ET INTERTANK DIVOT BREAKING UP AND FALLING AFT



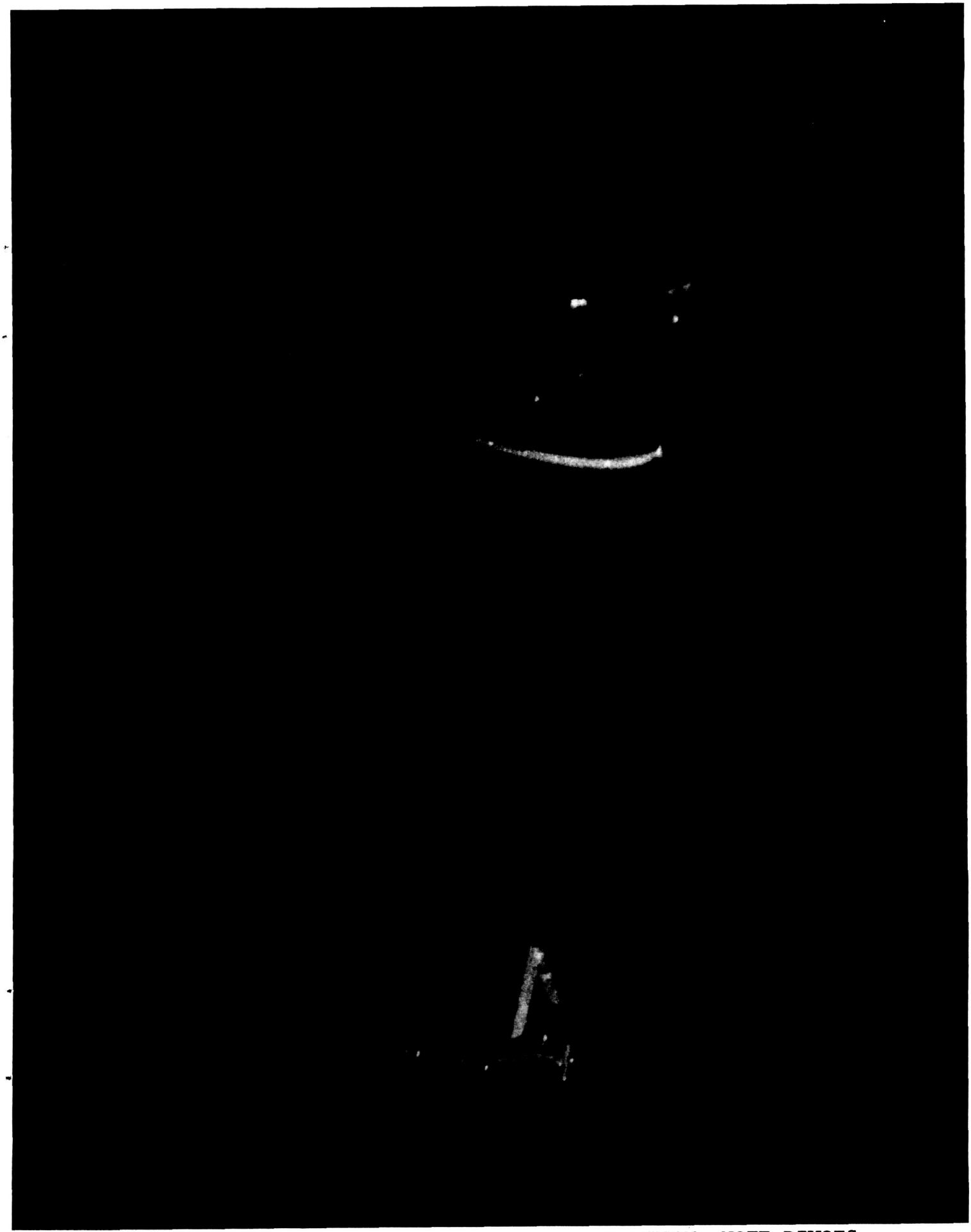
RED AND WHITE CHECKERED PAPER COVER COMES LOOSE FROM ORBITER FORWARD RCS THRUSTER



ORBITER FORWARD RCS PAPER COVER FELL AFT AND
CONTACTED WINDOW #4 LEAVING STREAKS OF RESIDUE



VIEW OF EXTERNAL TANK SHORTLY AFTER SEPARATION. NOTE DIVOTS, 14-20 INCHES IN DIAMETER, ON LH2 TANK-TO-INTERTANK FLANGE RAMP



VIEW OF EXTERNAL TANK SHORTLY AFTER SEPARATION. NOTE DIVOTS ON LH2 TANK-TO-INTERTANK FLANGE AND FOUR ON THRUST PANEL

6.1 POST-LAUNCH FILM AND VIDEO REVIEW

FILM ITEMS

EX1
400 FPS
16mm

Camera is located on MLP deck south of RH SRB exhaust duct and looks north to view RH SRB Heater Umbilical during ignition and liftoff.

Focus : OK
F. O. V.: GOOD VIEW OF HOLDDOWN POST #1 BUT CAMERA IS TOO FAR EAST TO VIEW RH SRB HEATER UMBILICAL.
Exposure: OK

Comments: AT SSME IGNITION, NUMEROUS VERY SMALL PARTICLES OF SRB AFT SKIRT INSTAFOAM ARE SHAKEN LOOSE AND BLOWN AROUND JUST TO THE RIGHT OF HOLDDOWN POST #1. ALSO AT SSME IGNITION, PARTICLES OF ICE FALL FROM ET/ORB UMBILICALS INTO THE FOV. DUST IS BLOWN OUT OF THE AFT SKIRT FOOT DEBRIS CATCHER CAVITY BY THE DOWN RUSH OF AIR AT AFTER SSME START-UP. CLEAN SEPARATION OF FIRING CABLES, HOLDDOWN POST SHOE SHIM IS INTACT, AND NO NSI FRAGMENTS DROP FROM AFT SKIRT HDP FOOT STUD HOLE. NO ANOMALIES ON JOINT HEATER UMBILICAL DISCONNECT. FOUR PIECES OF THERMAL CURTAIN TAPE HAVE COME LOOSE AT SRB IGNITION. TYPICAL WATER TROUGH MATERIAL, CORD, AND SRB THROAT PLUG MATERIAL PASS THROUGH FOV AFTER VEHICLE CLEARS FRAME.

EX2
400 FPS
16mm

Camera is located on the MLP deck west of RH SRB flame duct and looks east to view SRB Heater Umbilical during ignition and liftoff.

Comments: DID NOT RUN - FILM JAMMED.

EX3
400 FPS
16mm

Camera is located on the MLP deck east of LH SRB flame duct and looks west to view SRB Heater Umbilical during ignition and liftoff.

Focus : SLIGHTLY SOFT
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: WATER DELUGE DROPLETS ENTER FRAME FROM LEFT AND SPLASH AGAINST AFT SKIRT AND MLP DECK. JOINT HEATER UMBILICAL DOES NOT MOVE DURING SSME IGNITION AND SEPARATES CLEANLY AT T-0.

EX4 Camera is located on MLP deck south of LH SRB
400 FPS flame duct and looks north to view LH SRB Heater
16mm Umbilical during ignition and liftoff.

Focus : SLIGHTLY SOFT
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED PRIOR TO IGNITION

Comments: WATER DELUGE SPRAY ENTERS FRAME JUST PRIOR TO IGNITION. SMALL PIECES OF DEBRIS ARE PARTICLES OF INSTAFOAM FROM AFT SKIRT AND STIFFENER RINGS AND ICE FROM ET/ORB UMBILICALS. MOMENTARY FLASHES OCCUR AS HOLDDOWN POST STUD FRANGIBLE NUT ORDNANCE FIRES INSIDE OF BLAST CONTAINER AND IS VISIBLE THROUGH VENT HOLES. HOLDDOWN POST #5 SHOE SHIM IS INTACT AND NO NSI FRAGMENTS DROP FROM AFT SKIRT HDP FOOT STUD HOLE, THOUGH ONE DARK FRAGMENT MOVES HORIZONTALLY BETWEEN HDP SHOE AND AFT SKIRT FOOT (4400). ONE PIECE OF THERMAL CURTAIN TAPE IS LOOSE. JOINT HEATER UMBILICAL IS OBSCURED.

E-1 Camera is located on the NE corner of the MLP deck
400 FPS and views the lower ET, SRB's, and Orbiter.
16mm

Focus : OK
F. O. V.: OK, BUT UNUSUAL AMOUNT OF CAMERA SHAKE. LOOSE MOUNT?
Exposure: OK

Comments: ROFI'S IGNITE (FRAME 588) AND SSME #2 IGNITION (2525) IS NOMINAL. FROST, PARTICLES OF ICE, AND WATER CONDENSATE FALL FROM LH2 UMBILICAL (3270). T-0 OCCURS AT FRAME 4330. THREE PIECES OF DEBRIS PASS BY SSME PLUME JUST PRIOR TO LIFTOFF. MORE FROST AND ICE PARTICLES FALL FROM UMBILICAL AS VEHICLE ASCENDS (4775) AND CONTINUES UNTIL VEHICLE CLEARS FOV. ONE PIECE OF THERMAL CURTAIN TAPE HAS COME LOOSE ON THE RH SRB. NO VEHICLE DAMAGE IS VISIBLE. SOME WATER TROUGH MATERIAL IS BLOWN ACROSS THE MLP DECK.

E-2 Camera is located on the SE corner of the MLP deck
400 FPS and views Orbiter SSME and OMS engine nozzles.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME #3 (FRAME 2316) AND SSME #1 (2430) IGNITION IS NOMINAL. RCS PAPER COVERS BEGIN TO TEAR (2360). T-0 OCCURS AT FRAME 4385. A CLOUD OF GOX IS VISIBLE AS THE T-0 UMBILICAL CARRIER PLATE RETRACTS INTO THE TSM (4530). THE LH2 TSM DOOR CLOSES

PROPERLY (4817). RCS PAPER COVER FALLS BETWEEN SSME'S (4845). TWO PIECES OF THERMAL CURTAIN TAPE ARE LOOSE ON THE RH SRB. WATER VAPOR FALLS FROM THE LOWER AND CENTER SRB STIFFENER RINGS. A PIECE OF ICE DROPS FROM THE ET UPPER STRUT AREA (5225).

E-3
400 FPS
16mm

Camera is located on the SW corner of the MLP deck and views Orbiter SSME and OMS engine nozzles.

Focus : OK
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: ROFI'S IGNITE (FRAME 570). SSME IGNITION IS NOMINAL (#3-2320, #2-2370, #1-2430). RCS PAPER COVERS BEGIN TO TEAR AND COME LOOSE (2485). SOME HARMONIC VIBRATION OCCURS IN THE OMS NOZZLES DURING SSME STARTUP. T-0 OCCURS AT 4395. SOME LH2 VAPORIZES AS T-0 CARRIER PLATE IS RETRACTED. RCS PAPER COVER FROM LH STINGER +Z SIDE FLOATS AROUND LH OMS NOZZLE, FALLS PAST SSME NOZZLES, AND VAPORIZES IN SSME #1 PLUME (4600-4950).

E-4
400 FPS
16mm

Camera is located on the NW corner of the MLP deck and views lower ET, SRB's, and Orbiter.

Comments: DID NOT RUN - DOVETAIL CLAMP FAILURE.

E-5
400 FPS
16mm

Camera is located on the east side of the MLP deck and views the Orbiter RH wing, body flap, and lower ET/SRB.

Focus : OK
F. O. V.: OK
Exposure: OK, BUT SOMEWHAT DARK AROUND ET/ORB UMBILICALS

Comments: ROFI'S IGNITE (FRAME 387). SSME IGNITION IS NOMINAL (#3-2130, #2-2200). ICE PARTICLES FALL FROM LOX ET/ORB UMBILICAL (2540). T-0 OCCURS AT 3250. DURING SSME IGNITION FROST, ICE PARTICLES, AND VAPORS FALL (2600) FROM ET/ORB LH2 UMBILICAL AND ARE DRAWN UNDER BODY FLAP AND INTO SSME PLUME BY ASPIRATION (2910-3530). NO VEHICLE DAMAGE IS VISIBLE.

E-6
200 FPS
16mm

Camera is located on the east side of the MLP deck and views the RH lower Orbiter wing, body flap, ET lower LOX feedline, and ET/Orbiter umbilical area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VAPOR ENVELOPES THE LH2 FEEDLINE AND UMBILICAL AREA. THESE VAPORS BECOME MORE DENSE, THEN FLOW DOWNWARD ALONG -Y SIDE THE BODY FLAP. SSME #3 STARTS AT FRAME 1358. AT FRAME 1366, ICE BEGINS TO FALL FROM THE ET/ORB UMBILICALS. ONE LARGE PIECE OF ICE (MAJOR DIMENSION 6") FROM A LO2 UMBILICAL PURGE VENT FALLS AND BECOMES LODGED NEXT TO THE LOX PRESSURIZATION LINE. ICE CONTINUES TO FALL FROM THE UMBILICALS UNTIL LOV, BUT NO ORBITER IMPACTS ARE OBSERVED. AT FRAME 2253, A PARTICLE ORIGINATES FROM THE ET/ORB STRUCTURAL CONNECT AREA BENEATH THE BASE OF THE THRUST STRUT AND MOVES OUT AND DOWN ALONG THE WING. IT LEAVES THE FOV AT FRAME 2476.

E-7
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB northeast holddown post (HDP #4).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NUMEROUS PIECES OF SMALL DECK DEBRIS ARE VISIBLE AFTER SSME STARTUP. SRB HPU EXHAUST IS CLEARLY VISIBLE. AT FRAME 4362 TWO PIECES OF INSTAFOAM COME FROM BEHIND THE HDP #4 SHOE. THE HOLD DOWN STUD FRANGIBLE NUT ORDNANCE IS BLOWN AT FRAME 4189. NUMEROUS PIECES OF THROAT PLUG MATERIAL FLY OUT OF THE SRB EXHAUST HOLE WITH THE IGNITION OVERPRESSURE WAVE. SOME PIECES ARE PROPELLED HIGH ENOUGH TO EXIT THE FOV. NO DEBRIS EXITS THE SRB AFT SKIRT FOOT STUD HOLE. THE SRB NOZZLE EXIT PLANE APPEARS TO BE PARALLEL WITH THE DOGHOUSE COVER AT FRAME 4636. IT CANNOT BE DETERMINED IF THE DOGHOUSE COVERS WERE CLOSED WHEN THE SRB NOZZLE EXIT PLANE PASSED BY. ALL ALIGNMENT TARGETS REMAIN IN PLACE THROUGH LOV.

E-8
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB southeast holddown post (HDP #2).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: THE HOLD DOWN POST FRANGIBLE NUT ORDNANCE FIRES AT FRAME 4333. THREE PIECES OF THERMAL CURTAIN TAPE WERE LOOSE. STARTING AT FRAME 4408 NUMEROUS PIECES OF THROAT PLUG MATERIAL AND OTHER DEBRIS RIDE THE SRB IGNITION OVERPRESSURE WAVE OUT OF THE SRB FLAME HOLE. SOME PIECES TRAVEL HIGH ENOUH TO LEAVE FOV. PIECES FALL INTO THE SRB EXHAUST HOLE AS THE VEHICLE ASCENDS. THE HDP SHOE ROCKS VIOLENTLY AS THE VEHICLE RISES. THE GN2 PURGE IS ON AND GEYSERING AS THE VEHICLE RISES. THE INSTAFOAM AROUND THE HDP APPEARS TO BE TOO THICK. NO NSI OR FRANGIBLE NUT FRAGMENTS FALL FROM THE SRB AFT SKIRT FOOT STUD HOLE. AT FRAME 4556, ONE 2" PIECE OF INSTAFOAM FALLS THROUGH THE FRAME AND HITS THE MLP DECK. ALL ALIGNMENT TARGETS ARE IN PLACE AT LOV.

E-9 Camera is located on the MLP deck and views the
400 FPS RH SRB southwest holddown post (HDP #1).
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SMALL DEBRIS PARTICLE TRAVELS (FRAME 850) INTO TOP OF FRAME, BOUNCES ON MLP DECK IN FOREGROUND AND FALLS IN RH SRB FLAME HOLE. PIECE OF TAPE LOCATED (2574) UNDER HIGH SPEED CAMERA IN FOREGROUND. ICE PARTICLE FALLS INTO FRAME (3534) AND BOUNCES ON MLP DECK. SMALL PARTICLES COME OUT OF GAP IN MLP DECK PLATING. SRB T-0 (4307) HDP BOLT FIRES. MANY PARTICLES OF THROAT PLUG MATERIAL 1 - 4" IN LENGTH FALL INTO MLP HOLE DURING SRB EARLY ASCENT. PIECES OF AFT SKIRT INSTAFOAM COME OUT OF RH SRB FLAME HOLE. THREE PIECES OF THERMAL CURTAIN TAPE PARTIALLY COME LOOSE FROM RH SRB AT SRB IGNITION.

E-10 Camera is located on the MLP deck and views the
400 FPS RH SRB northwest holddown post (HDP #3).
16mm

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4394. TWO PIECES OF THERMAL CURTAIN TAPE COME LOOSE FROM RH SRB AT SRB IGNITION. HOLDDOWN POST DOGHOUSE BLAST COVER CLOSES AFTER THE SRB NOZZLE EXTENSION PASSES. TWO 2" PIECES OF INSTAFOAM BREAK LOOSE FROM AFT SKIRT ADJACENT TO HOLDDOWN POST. NO NSI OR FRANGIBLE NUT FRAGMENTS DROP FROM AFT SKIRT HOLDDOWN POST DEBRIS CONTAINER. FACILITY DEBRIS PASSES THRU FRAME AFTER VEHICLE CLEARS FOV.

E-11
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northeast holddown post (HDP #7).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 4438. ONE PIECE OF THERMAL CURTAIN TAPE COMES LOOSE AT SRB IGNITION. THREE LARGE PIECES (3"X 2"X 1", 6"X 4"X 1", AND 7"X 5"X 1" IN SIZE) AND NUMEROUS SMALLER PIECES OF INSTAFOAM BREAK LOOSE FROM AFT SKIRT TO THE LEFT OF THE HOLDDOWN POST. A LONG PIECE OF WATER TROUGH ATTACHMENT CORD WHIPS AROUND VIOLENTLY AFTER IGNITION. THE HOLDDOWN POST DOGHOUSE BLAST COVER CLOSES JUST BEFORE THE SRB NOZZLE EXTENSION PASSES.

E-12
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southeast holddown post (HDP #5).

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: TAPE IS PRESENT IN FOREGROUND ON MLP DECK. PARTICLES FALL THROUGH FRAME AFTER SSME IGNITION. LARGE PARTICLE FALLS THROUGH LEFT SIDE OF FRAME (2998). ICE PARTICLE FALLS THROUGH FRAME (3628) AND BOUNCES ON MLP DECK IN FOREGROUND. HOLDDOWN POST FRANGIBLE NUT ORDNANCE FIRES (4085) AND FLASH IS VISIBLE THROUGH BLAST CONTAINER VENT HOLES. THROAT PLUG PARTICLES AND GASES COME FROM SRB EXHAUST HOLE IN EARLY ASCENT. NO THERMAL CURTAIN TAPE IS LOOSE AS SRB CLEARS FRAME (4387).

E-13
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB southwest holddown post (HDP #6).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: THE HOLD DOWN PYROS FIRE AT FRAME 4333. AT FRAME 4406 ONE PIECE OF THROAT PLUG EXITS THE SRB EXHAUST HOLE FROM BEHIND THE POST, THEN RE-ENTERS THE EXHAUST HOLE. THE HDP SHOE ROCKS VIOLENTLY AS THE VEHICLE RISES. NO NSI FRAGMENTS DROP FROM THE AFT SKIRT HDP STUD HOLE. ALIGNMENT TARGETS ARE IN PLACE AT LOV.

E-14
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB northwest holddown post (HDP #8).

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: HOLD DOWN PYROS FIRE AT FRAME 4402. TWO NSI FRAGMENTS DROP FROM THE AFT SKIRT STUD HOLE AFTER THE AFT SKIRT FOOT PASSES THE HOLDDOWN POST DOGHOUSE BLAST COVER. EXHAUST GASES OBSCURE THE CLOSING OF THE DOGHOUSE COVER. ALIGNMENT TARGETS ARE IN PLACE AT LOV.

E-15
400 FPS
16mm

Camera is located on the MLP deck and views the RH SRB skirt, sound suppression water troughs, and RH lower Orbiter body flap.

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: SSME #3 IGNITION OCCURS AT FRAME 2435. AT SSME IGNITION, THE ICE/FROST BUILD-UP FROM SSME #3 GOX OVERBOARD VENT FALLS INTO ENGINE PLUME. LOX UMBILICAL ICE PARTICLES (FRAME 3041) FALL AFT OF SSME. NUMEROUS PIECES OF ICE FROM LOX T-0 UMBILICAL DROP AT FRAME 2984. GAP FILLER FALLS AT FRAME 3035, ANOTHER PARTICLE AT FRAME 3176. SRB IGNITION T-0 OCCURS AT FRAME 4470. TWO PIECES OF THERMAL TAPE COME LOOSE AND FALL INTO SRB HOLE. PIECES OF THROAT PLUG MATERIAL (4595) COME OUT OF SRB FLAME HOLE. TWO PIECES OF LOOSE THERMAL CURTAIN TAPE ARE VISIBLE DURING SRB EARLY ASCENT. LARGE PARTICLE FALLS FROM SRB AFT SKIRT FOOT INTO HDP #3 AREA. BLAST SHIELD FOR HDP #3 CLOSES (4905) FOLLOWED BY BLAST SHIELD FOR HDP #4. WATER TROUGH AND THROAT PLUG MATERIAL FALLS AS SRB CLEARS FRAME.

E-16
400 FPS
16mm

Camera is located on the MLP deck and views the LH SRB skirt, sound suppression water troughs, and LH lower Orbiter body flap.

Comments: DID NOT RUN - LOOSE CLAMPS

E-17
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LO2 T-0 Umbilical and TSM.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NUMEROUS PARTICLES (FRAME 2088) ENTER TOP OF FOV, PROBABLY LOX UMBILICAL ICE. RCS BUTCHER PAPER RUPTURES AT FRAME 2115, TEARS AWAY, AND FALLS TOWARD THE SSME FLAME HOLE. ICE BEGINS FALLING FROM T-0 UMBILICAL AT FRAME 2317, SOME OF WHICH HITS THE SSME #3 NOZZLE. PRIOR TO T-0, SEVERAL SMALL PARTICLES COME FROM THE -Z SIDE OF THE BODY FLAP IN THE HINGE AREA. VAPOR IS VISIBLE AT ET/ORB UMBILICAL. THREE DINGS IN THE AFT HEAT SHIELD AREA OCCUR DURING LIFTOFF. ONE OCCURS ON THE +Y SIDE OF THE SSME #3 EYEBALL AT FRAME 2514. A SECOND OCCURS AT FRAME 2505 ON -Z +Y SIDE OF THE BODY FLAP. A THIRD OCCURS AT FRAME 2256 JUST AFT OF THE AFT RCS STINGER -Z FIRING NOZZLE. RAPID BODY FLAP MOVEMENTS ARE CAUSED BY SSME IGNITION. SSME #3 BELL OSCILLATES DURING PLUME STABILIZATION. ICE FROM LOX UMBILICAL FALLS THROUGH FRAME AFTER SSME START UP. MUCH VAPOR COMES FROM LOX T-0 UMBILICAL DURING SEPARATION, BUT RETRACTION IS NOMINAL. THE VAPOR CLOUD ENVELOPES THE SSME #3 NOZZLE BEFORE DISSIPATING. A LARGE PIECE OF UMBILICAL ICE APPEARS AT FRAME 3495 IN MIDDLE OF FRAME. UMBILICAL ICE CONTINUES TO FALL DURING EARLY ASCENT. A 4"X4"X1" PARTICLE, BROWN IN COLOR, ENTERS THE FIELD OF VIEW AT FRAME 3195 AND PASSES -Z SIDE OF THE RIGHT INBOARD ELEVON.

E-18
400 FPS
16mm

Camera is located on the MLP deck and views the -Z side of the LH2 T-0 umbilical and TSM.

Comments: TERMINATED PRIOR TO T-0 - DOVETAIL CLAMP FAILURE.

E-19
400 FPS
16mm

Camera is located on the SE side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: IGNITERS START AT FRAME 719. SSME #3 IGNITION OCCURS AT FRAME 2456, SSME #2 AT FRAME 2513, AND SSME #1 AT FRAME 2567. PAPER COVERS ON RCS NOZZLES RUPTURE (FRAME 2549) EARLY IN SSME IGNITION SEQUENCE. SSME NOZZLES SHOW CONSIDERABLE MOVEMENT BEFORE PLUMES STABILIZE. MANY ICE/FROST PARTICLES FALL FROM LOX

TSM CARRIER PLATE DURING SSME IGNITION. ONE PARTICLE ENTERS THE FOV FROM THE +Z SIDE OF THE RH OMS NOZZLE MOVING DOWNWARD (2666). VIEW OF THE PARTICLE IS LOST AS IT PASSES THE SSME #1 EXIT PLANE. A TILE CHIP IS SHAKEN LOOSE FROM RH RCS STINGER AT SSME #1 STARTUP (2703). ANOTHER PARTICLE ENTERS THE FRAME FROM THE +Z SIDE OF THE RH STINGER AND CONTINUES DOWNWARD UNTIL IT EXITS THE FRAME (2722). SIX GAP FILLERS APPEAR FROM THE -Z SIDE OF SSME #1 ENGINE MOUNTED HEAT SHIELD (3191). LH2 TSM DOOR CLOSES NORMALLY. APPROXIMATELY 30 PARTICLES ENTER UPPER LEFT CORNER OF FRAME (3237), CROSS THE RIGHT SIDE OF THE VERTICAL STABILIZER/SSME #1, AND PASS UNDER THE RH OMS NOZZLE. DURING EARLY ASCENT (5044), A PIECE OF RCS PAPER COVER FALLS FROM SSME #1 AREA. ICE/FROST PARTICLES FALL FROM ET/ORB LH2 UMBILICAL (5144).

E-20
400 FPS
16mm

Camera is located on the SW side of the MLP deck and views the SSME/OMS nozzles and Orbiter aft heat shield area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE FORMS ON SSME OVERBOARD BLEED VENTS AND FALLS AT FRAME 2780. PAPER COVERS ON RCS NOZZLES RUPTURE EARLY IN SSME IGNITION SEQUENCE AT FRAME 2492. SSME NOZZLES OSCILLATE DURING START-UP. LH2 TSM CARRIER PLATE ICE FALLS IN FOREGROUND AT SSME IGNITION. SSME #3 STARTS AT FRAME 2358, SSME #2 AT FRAME 2410, AND SSME #1 AT FRAME 2463. WIRE-LIKE LAUNCH PAD DEBRIS ABOUT 2 FEET LONG APPEARS AT FRAME 2928 AS IT PASSES THROUGH TSM AREA. GASES AND ICE FALL FROM LH2 TSM AT DISCONNECTION. PARTICLES FALL FROM LO2 TSM CARRIER PLATE. TSM DOOR CLOSURE IS NORMAL. AT FRAME 3348 A PARTICLE MOVES ACROSS THE SSME #2 HEAT SHIELD AND IMPACTS THE SSME #2 ENGINE BELL. IT DOES NOT DISINTEGRATE WHEN IT PASSES BY THE EXIT PLANE.

E-21
200 FPS
16mm

Camera is located inside the LO2 TSM and views the disconnection of the T-0 umbilical.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: LOX T-0 CARRIER PLATE SEPARATES FROM THE ORBITER NORMALLY. NO VEHICLE ANOMALIES.

E-22 Camera is located inside the LH2 TSM and views
200 FPS the disconnection of the T-0 umbilical.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: PURGE BARRIER IS LOOSE AT TOP OF TSM DOOR AND SEPARATES COMPLETELY AT SSME IGNITION. LH2 CARRIER PLATE DISCONNECT FROM ORBITER IS NORMAL. NO VEHICLE ANOMALIES.

E-23 Camera is located on the MLP deck and views the
400 FPS RH OMS engine nozzle.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: FREE HYDROGEN IS BURNING (FRAME 2460). THE SSME START SEQUENCE BEGINS AT FRAME 2566. AFTER SSME START, NUMEROUS SMALL PIECES FALL FROM TOP TO BOTTOM OF SCREEN. STARTING AT FRAME 2689 THE RCS PAPER COVER RUPTURES AND TEARS OFF. THE BUTCHER PAPER CHECKERBOARD PATTERN IS CLEARLY VISIBLE. TWO BASE HEAT SHIELD TILE DINGS OCCUR JUST OUTBOARD OF SSME #1. ONE BECOMES VISIBLE AT FRAME 2697, THE NEXT AT FRAME 3240. STARTING AT FRAME 2856 LO2 T-0 UMBILICAL ICE PARTICLES FALL FROM BEHIND THE STINGER. AT FRAME 3382 ONE GAP FILLER COMES FROM BEHIND SSME #1. LO2 EO UMBILICAL ICE CONTINUES TO FALL AS VEHICLE CLIMBS OUT OF VIEW. LO2 T-0 UMBILICAL RETRACT APPEARS NOMINAL. A LARGE GOX CLOUD FROM THE T-0 DISCONNECT ENVELOPES SSME #3, THEN DISAPPEARS. ONE TILE DING IS VISIBLE ON THE BASE OF THE STINGER AS THE VEHICLE RISES. ONE TILE DING APPEARS BEHIND THE RH OMS NOZZLE DURING CLIMB OUT.

E-24 Camera is located on the MLP deck and views the
400 FPS LH OMS engine nozzle.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE/FROST HAS FORMED ON THE SSME #2 ENGINE MOUNTED HEAT SHIELD AND REMAINS THROUGH LOV. FREE HYDROGEN BURNS PRIOR TO SSME START. SSME #1 IGNITION OCCURS AT FRAME 2505. FOUR TILE

DINGS OCCUR ON THE BOTTOM OF THE LH STINGER AT FRAMES 2509, 2523, 2553, AND 2563. ICE FALLS BEHIND THE LH STINGER FROM THE LH2 T-0 UMBILICAL (2673). THE RCS PAPER COVER BEGINS TO RUPTURE AT FRAME 2841. A Q-FELT PLUG FROM THE SSME #1 REGION COMES INTO VIEW (3191).

E-25 Camera is located on the east side of the MLP and
400 FPS views between Orbiter and ET/SRB during liftoff.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME IGNITION OCCURRED AT FRAME 1637. A LARGE AMOUNT OF ICE/FROST/VAPOR FALLS FROM THE LH2 UMBILICAL (FRAME 1987), BUT NO ICE PARTICLES APPEAR TO DAMAGE ORBITER TILES. VAPOR CONTINUES TO EMANATE FROM LH2 UMBILICAL AREA UNTIL TOWER CLEAR. BODY FLAP/ELEVON MOVEMENT OCCURS JUST PRIOR LIFTOFF. NUMEROUS PIECES OF FACILITY DEBRIS ARE VISIBLE NEAR CAMERA JUST PRIOR TO LOV.

E-26 Camera is located on the west side of the MLP and
400 FPS views between Orbiter and ET/SRB during liftoff.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK
Other : TOO MUCH WATER ON LENS

Comments: A LARGE AMOUNT OF ICE/FROST/VAPOR FALLS FROM THE LH2 UMBILICAL CONCURRENT WITH SSME START UP (FRAME 1529). VAPOR CONTINUES TO EMANATE FROM THE LH2 UMBILICAL THROUGH TOWER CLEAR (FRAME 4438). NO ICE PARTICLE STRIKES ON THE ORBITER ARE VISIBLE. BODY FLAP/ELEVON MOVEMENT BEGINS AFTER SSME START UP AT ABOUT FRAME 2000. T-0 OCCURS AT FRAME 3606.

E-27 Camera is located on the MLP deck and views RH SRB
400 FPS northwest holddown post (HDP #3) blast cover.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: TWO PIECES OF SRB THERMAL CURTAIN TAPE ARE LOOSE FRAME 4747. HDP #3 AND #4 DOGHOUSE COVERS APPEAR TO CLOSE SIMULTANEOUSLY BUT LATE. NO DEBRIS FALLS FROM THE SRB AFT SKIRT HDP BOLT DEBRIS CONTAINERS. A SMALL PIECE OF INSTAFOAM BREAKS OFF THE AFT SKIRT CLOSEOUT NEAR HDP #3 AT T-0 (4338). SMALL PIECES OF THROAT PLUG MATERIAL ARE EJECTED UPWARD FROM THE FLAME HOLE JUST AFTER T-0.

E-28
400 FPS
16mm

Camera is located on the MLP deck and views LH SRB northeast holddown post (HDP #7) blast cover.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE OBSCURES VIEW. SSME STARTUP BEGINS AT FRAME 2199. HOLD DOWN PYROS BLOW AT FRAME 4188. AT FRAME 4257 TWO FLAT PIECES OF FOAM COME FROM BEHIND HDP #7. FOUR PIECES OF SRB THERMAL CURTAIN TAPE ARE LOOSE NEAR HDP #7 AND ANOTHER PIECE IS VISIBLE NEAR HDP #1. THE HDP DOGHOUSE BLAST COVERS, WHICH MOVE SIMULTANEOUSLY, ARE CLOSED BY FRAME 4626 PRIOR TO THE SRB NOZZLE EXIT PLANE PASSING.

E-30
400 FPS
16mm

Camera is located on the FSS 195 foot level and views LH SRB and sound suppression water troughs.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DROPLETS FROM FSS DELUGE ENTER LEFT SIDE FOV. NUMEROUS ICE/FROST PARTICLES AND VAPORS FALL FROM THE LH2 UMBILICAL AT SSME IGNITION AT ABOUT FRAME 2015. NO TILE IMPACTS ARE NOTED. INTENSE PLUME BRIGHTNESS SHORTLY AFTER IGNITION WASHES OUT DETAIL. NUMEROUS PIECES OF FACILITY DEBRIS NEAR CAMERA APPEAR IN EXHAUST CLOUD AFTER LIFTOFF.

E-31
100 FPS
16mm

Camera is located on the FSS 95 foot level and views the LH Orbiter wing, body flap, and ET/Orbiter LH2 umbilical area.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: DELUGE WATER FROM FSS OBSCURES DETAIL. MORE VAPORS THAN USUAL AT THE ET/ORB LH2 UMBILICAL ARE PRESENT PRIOR TO SSME STARTUP. AT SSME IGNITION (FRAME 622) DENSE VAPORS AND ICE/FROST FALL FROM THE UMBILICAL AND SOME ICE/FROST PARTICLES BRUSH AGAINST THE BODY FLAP, BUT NO ORBITER TILE DAMAGE IS VISIBLE. IGNITION AND LIFTOFF CAUSES ELEVONS TO MOVE.

E-33 Camera is located on the FSS 235 foot level and
400 FPS views the ET GH2 vent line and GUCP.
16mm

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: HEAVY FSS DELUGE WATER OBSCURES VIEW. FROST IS VISIBLE ON UNINSULATED SIDES AND BOTTOM OF ET GUCP. SEVERAL SMALL PIECES OF ICE/FROST FALL DURING SSME STARTUP AND LIFTOFF. GUCP SEPARATION IS NORMAL. ET FOAM IS PULLED LOOSE FROM RH SIDE OF ET GUCP PLATE CUTOUT. NO BOOSTER ANOMALIES ARE VISIBLE AS VEHICLE RISES.

E-34 Camera is located on FSS at 255 foot level and
400 FPS views upper Orbiter tile surfaces.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: RCS PAPER COVERS PULL LOOSE FROM LH STINGER (FRAME 4240). ICE/FROST PARTICLES FALL FROM LH2 ET\ORB UMBILICAL (4275). VAPOR IN THE VICINITY OF THE LH2 ET\ORB UMBILICAL IS DENSER THAN USUAL AND CONTINUOUS WHILE IN VIEW - MAY BE LIQUID AIR VAPORIZING DUE TO A POSSIBLE COLD SHORT IN THE TPS. THIS LIQUID RUNS DOWN THE BODY FLAP, SEPARATES FROM THE VEHICLE, AND VAPORIZES. ICE/FROST PARTICLES BRUSH BODY FLAP AS VEHICLE RISES (4420), BUT NO TILE DAMAGE IS VISIBLE. MANY PIECES OF THIN AND IRREGULARLY SHAPED DEBRIS IN THE PLUME AFTER THE VEHICLE HAS CLEARED THE FOV (5884).

E-35 Camera is located on the FSS 255 foot level and
400 FPS views the mid-Orbiter/ET/SRB area.
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: T-0 OCCURS AT FRAME 3355. ICE/FROST PARTICLES FROM THE GUCP FALL ALONG THE -Z SIDE OF THE LH SRB (4037). SEVERAL PIECES OF FROST FROM THE GH2 VENT CROSS COUNTRY LINE FALL ALONG THE -Y SIDE OF THE LEFT BOOSTER, BUT NONE IMPACT THE ORBITER WING. THE ET/ORB LH2 UMBILICAL IS OBSCURED BY DENSE VAPORS - HEAVIER THAN USUAL. RCS PAPER COVERS ARE TORN FROM THE LH STINGER AS THE VEHICLE RISES. MANY SMALL PIECES OF FACILITY DEBRIS APPEAR IN THE PLUME WELL AFTER THE VEHICLE HAS CLEARED THE FOV (6550).

E-36 Camera is located on the FSS 255 foot level and
400 FPS views lower Orbiter, ET, SRB's, and water trough.
16mm

Focus : OK
F. O. V.: OK
Exposure: SLIGHTLY OVEREXPOSED

Comments: SSME IGNITION OCCURS AT FRAME 962 WITH T-0 AT 3010. SMALL PIECES OF FROST FROM THE GH2 VENT CROSS COUNTRY LINE AND WATER DROPS FROM THE FSS DELUGE FALL ALONG THE -Y SIDE OF THE LH SRB, BUT NONE IMPACT THE ORBITER WING. THE ET\ORB LH2 UMBILICAL IS OBSCURED BY DENSE VAPORS. MANY SMALL PIECES OF FACILITY DEBRIS APPEAR IN THE PLUME WELL AFTER THE VEHICLE HAS CLEARED THE FOV.

E-39 Camera is located on the FSS 185 foot level and
400 FPS views GH2 vent line latchback.
16mm

Focus : OK
F. O. V.: OK
Exposure: UNDEREXPOSED
Other : PROBABLY SHOULD DISCONTINUE THIS ITEM

Comments: VIEW IS ALMOST TOTALLY OBSCURED BY WATER DELUGE, BUT ENOUGH DETAIL CAN BE DISCERNED TO CONFIRM NO GH2 VENT ARM REBOUND.

E-40 Camera is located on the FSS 275 foot level and
400 FPS views the ET ogive, SRB nosecone, and Orbiter
16mm tiled surfaces.

Focus : OK
F. O. V.: EXCELLENT, MUCH BETTER THAN PREVIOUS LOCATION
Exposure: OK

Comments: FIRST FORWARD MOTION OF THE VEHICLE OCCURS AT FRAME 2715. A LIGHT LAYER OF FROST HAS FORMED ON THE -Y GOX VENT LOUVER. NO WING OR ELEVON DAMAGE IS VISIBLE. ICE/FROST PARTICLES CONTINUE TO FALL FROM THE ET/ORB LH2 UMBILICAL, WHICH IS STILL OBSCURED BY DENSE VAPORS. MOST OF THE RCS PAPER COVERS HAVE BEEN TORN FROM THE LH STINGER. CONDENSATE FALLS FROM ORBITER SPLIT SPEEDBRAKE/RUDDER (4345). MANY PIECES OF DEBRIS ENTER FOV AFTER VEHICLE HAS CLEARED THE TOWER.

E-41
400 FPS
16mm

Camera is located on the FSS 255 foot level and views the GH2 vent line during rotation. Also shows clearance between structure and SRB aft skirt.

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: NINE PARTICLES BACKLIT BY SUN FALL FROM FSS 275 FT LEVEL OR GOX VENT ARM BETWEEN SSME IGNITION AND LIFTOFF. PARTICLES ARE MOST LIKELY LARGE DROPS OF WATER FROM THE FSS WATER DELUGE PASSING CLOSE TO CAMERA LENS (NOTE HIGH RELATIVE VELOCITY COMPARED TO VEHICLE MOVEMENT IN THIS HIGH SPEED FILM ITEM). RUST-COLORED DELUGE WATER SPRAYS FROM INTERTANK ACCESS ARM STRUCTURE. GH2 VENT LINE DISCONNECT AND LATCHBACK ARE NOMINAL. GH2 VENT LINE DOES NOT CONTACT LH SRB. A LARGE PIECE OF DEBRIS (FRAME 4363) PASSES THROUGH BOTTOM OF FRAME BEFORE VEHICLE CLEARS TOWER. NO VEHICLE ANOMALIES ARE VISIBLE. MANY PIECES OF FACILITY DEBRIS PASS THROUGH FOV AFTER VEHICLE CLEARS TOWER.

E-42
400 FPS
16mm

Camera is located on the FSS 185 foot level and views the GH2 vent line drop, deceleration, and latchback.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: GH2 VENT LINE RETRACTION AND LATCHBACK IS NORMAL. VENT LINE TAKE-UP CABLE IS NOT RETRACTED AS QUICKLY AS VENT LINE RETRACTS LEAVING SLACK IN THE CABLE. CONDENSATE/WATER VAPOR IS VISIBLE NEAR THE END OF THE VENT LINE PRIOR TO AND DURING LATCHBACK. SEVERAL PIECES OF FACILITY DEBRIS ENTERS FOV AFTER VEHICLE CLEARS TOWER.

E-43
200 FPS
16mm

Camera is located on pad surface and views sound suppression water flow distribution beneath MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE FALLS FROM MLP CRYOGENIC LINES. FREE HYDROGEN CONTINUES TO BURN UNDER MLP AFTER SSME IGNITION. NO UNUSUAL DEBRIS IS VISIBLE IN PLUME EXCEPT FOR ONE SOLID OBJECT AT FRAME 2411 - VEHICLE HAS ALREADY CLEARED THE TOWER.

E-44
400 FPS
16mm

Camera is located on the FSS 155 foot level and views the LH OMS Pod leading edge tiles during ignition and liftoff.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: LH2 T-0 UMBILICAL RETRACTION IS NORMAL. ORBITER TPS IS INTACT AND UNDAMAGED AS OMS POD PASSES THROUGH FOV. NO VEHICLE ANOMALIES OBSERVED.

E-48
400 FPS
16mm

Camera is located on the FSS 215 foot level (ET Intertank access arm structure) and views the GH2 vent line during GUCP disconnection, rotation, and latchback

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: CONSIDERABLE AMOUNT OF WATER DELUGE IN FOV. NOMINAL SEPARATION OF GUCP AND RETRACTION OF GH2 VENT ARM. LIGHT FROST REMAINS ON ET AFTER GUCP DISCONNECT AND SOME PARTICLES OF ICE/FROST FALL. RSS ANTENNA RAMP IS INTACT UNTIL CLEAR OF FRAME. LIGHT SPOT ON ET THRUST PANEL IS A REPAIR AREA. VAPORS ARE VISIBLE ON ET AFT DOME AND ET/ORB LH2 UMBILICAL. LOWER EB FITTING STILL COVERED BY ICE/FROST.

E-50
400 FPS
16mm

Camera is located at camera site 1 at NE pad perimeter and views entire GH2 vent line and GUCP during rotation and latchback.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: RUST-COLORED DELUGE WATER SPRAYS FROM THE ET INTERTANK ACCESS ARM STRUCTURE TOWARD THE VEHICLE. GH2 VENT LINE DISCONNECT AND LATCHBACK ARE NORMAL. GH2 VENT LINE DOES NOT CONTACT LH SRB. VENT LINE TAKE-UP CABLE IS SLACK DURING LINE RETRACT/LATCHBACK.

E-52
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: EXCELLENT
Exposure: OK

Comments: SSME IGNITION IS NOMINAL. WATER DELUGE SPRAY FROM THE FSS IS BLOWN EAST TOWARD VEHICLE. DENSE VAPORS ARE VISIBLE AROUND ET/ORB LH2 UMBILICAL AT TOWER CLEAR. CONDENSATE ON ET AFT DOME HAS BEGUN TO VAPORIZE. VAPORS AROUND SRB NOZZLE EXTENSION ARE CAUSED BY WATER FROM STIFFENER RINGS VAPORIZING AND OUTGASSING OF INSTAFOAM. FWD RCS PAPER COVERS ARE INTACT THRU FRAME 1425. TORN AFT RCS PAPER COVERS BEGIN TO FALL FROM VEHICLE THROUGH EARLY ASCENT (1784). AT FRAME 2025, A 6-INCH PIECE OF FOAM MATERIAL FALLS BETWEEN THE INBOARD ELEVON AND BODY FLAP - ORIGINATES FROM BETWEEN THE LH SRB/ET AND ORBITER AREA. APPROXIMATELY 50 PIECES OF UMBILICAL ICE/FROST, INSTAFOAM, AND AFT RCS PAPER COVERS ARE VISIBLE THROUGH EARLY ASCENT. A PIECE OF MATERIAL 8-INCHES IN DIAMETER PASSES OVER THE RH WING JUST OUTBOARD OF THE OMS POD (2253) AND IS PROBABLY ONE OF THE FWD RH RCS PAPER COVERS. ANOTHER 8-INCH DIAMETER PIECE OF MATERIAL PASSES OVER THE LH WING (2505) JUST OUTBOARD OF THE OMS POD AND IS MOST LIKELY ONE OF THE FWD LH RCS PAPER COVERS.

E-53
96 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of middle one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: GH2 VENT ARM RETRACTS AND LATCHES NORMALLY. CONDENSATE ON ET AFT DOME BEGINS TO VAPORIZE. SEVERAL BIRDS ARE VISIBLE, BUT NONE IMPACT ORBITER. SAME ICE PARTICLES, PIECES OF INSTAFOAM, AND AFT RCS PAPER COVERS ARE VISIBLE AS DESCRIBED IN E-52. FWD RCS PAPER COVERS PASS OVER RH WING (2190) AND LH WING (2437).

E-54
100 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Comments: NEW PHOTOSONICS CAMERA ITEM DID NOT RUN. FILM JUMPED OUT OF SPROCKETS AND TIMING WAS INCOMPATIBLE WITH KSC SYSTEM.

E-57
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of lower one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED
Comments: CONDENSATE COMES OFF THE ET AFT DOME AND THE BOOSTER STIFFENER RINGS. NO SLIDEWIRE BASKETS RELEASE THROUGH TOWER CLEAR. ICE PARTICLES AND VAPORS FALL FROM ET/ORB LH2 UMBILICAL. NO DETAIL VISIBLE IN INTERTANK AREA WHERE TWO FOOT CRACK WAS LOCATED. ICE PARTICLES FALL FROM LH LOWER EB FITTING. JUST PRIOR TO, AND RIGHT AT LIFTOFF, 3 BIRDS ARE IN THE VICINITY OF THE VEHICLE AND PASS BETWEEN THE CAMERA AND THE FSS HEADING OUTWARD - NO IMPACTS TO THE VEHICLE. FORWARD RCS PAPER COVER TRAVELS PAST THE RIGHT SIDE OF THE FUSELAGE (FRAME 2190).

E-58
96 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of center one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SEE COMMENTS FOR E-57, E-59.

E-59
100 FPS
35mm

Camera is located at camera site 6 on the NW pad perimeter. Remote tracking of upper one-third of launch vehicle from ignition to 1200 feet.

Focus : OK
F. O. V.: OK INITIALLY, INCONSISTENT TRACKING
Exposure: OK

Comments: WATER DELUGE SPRAY BLOWS EAST OFF OF FSS. A BIRD ENTERS THE FIELD OF VIEW FROM THE LEFT SHORTLY AFTER LIFTOFF. BIRD PASSES BETWEEN CAMERA AND VEHICLE. NO CONTACT WITH THE VEHICLE IS VISIBLE. NO VEHICLE ANOMALIES THROUGH 1200 FEET. NO DEBRIS FROM FORWARD ET OR SRB'S IS VISIBLE. VAPOR IN THE AREA OF THE LH2 UMBILICAL (AT TOWER CLEAR) COULD BE ANY COMBINATION OF BOOSTER PLUME, VAPORIZING CONDENSATE ON AFT DOME, AND VAPORIZING LIQUID AIR FROM THE LH2 UMBILICAL.

E-60
96 FPS
35mm

Camera is located on north pad perimeter at camera site 1 and views the entire launch vehicle, FSS, and MLP zero level.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAY BLOWS EAST OFF OF FSS. SSME IGNITION IS NOMINAL. ICE ON CROSS COUNTRY LINES IS THROWN UPWARD BY SRB IGNITION. GH2 VENT ARM RETRACTS AND LATCHES PROPERLY. THERE IS NO EVIDENCE THAT THE TWO SLIDE WIRE BASKETS FOUND RELEASED POST-LAUNCH, WERE RELEASED PRIOR TO TOWER CLEAR. JUST AFTER IGNITION, TWO PPU ELECTRICAL BOX COVERS FROM THE NORTHWEST CORNER OF THE MLP DECK ARE BLOWN OUTWARD AWAY FROM THE VEHICLE IN A NORTHWESTERLY DIRECTION ABOUT 500 FEET. WATER VAPORIZES FROM STIFFENER RINGS OF BOTH SRB'S AND VAPOR CONTINUES TO EMANATE FROM ET/ORB LH2 UMBILICAL AS VEHICLE RISES. CONDENSATE FROM ET AFT DOME BEGINS TO VAPORIZE. NO VEHICLE ANOMALIES AT LIFTOFF. TWO PIECES OF FACILITY DEBRIS ARE VISIBLE IN THE PLUME WELL AFTER THE VEHICLE AS CLEARED THE FOV.

E-61
100 FPS
35mm

Camera is located at camera site 2 on the east pad perimeter and views the launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ICE ON CROSS COUNTRY LINE IS SHAKEN LOOSE BY SSME IGNITION. T-0 OCCURS AT 14:57:00.203. FIVE BIRDS FLY FROM EAST SIDE OF MLP SOUTHEAST AWAY FROM VEHICLE. WATER DELUGE SPRAY BLOWS EAST FROM FSS. TWO COVERS FROM PPU ELECTRICAL BOXES ON THE NORTHWEST CORNER OF THE MLP DECK ARE BLOWN IN A NORTHWESTERLY

DIRECTION AT 14:57:03.911 AND 14:57:04.155 SECONDS, RESPECTIVELY. VAPOR CONTINUES TO EMANATE FROM THE ET\ORB LH2 UMBILICAL AS THE VEHICLE RISES THROUGH TOWER CLEAR. WATER CONDENSATE ON ET AFT DOME ALSO BEGINS TO VAPORIZE. CONDENSATE FALLS FROM THE SPLIT RUDDER SPEEDBRAKE. NO VEHICLE TPS ANOMALIES.

E-62
96 FPS
35mm

Camera is located on the SE pad perimeter at camera site 3 and views entire vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAY FROM FSS AND INTERTANK ACCESS ARM STRUCTURE IS BLOWN DOWN -Y SIDE OF VEHICLE. SSME IGNITION CAUSES ICE TO FALL FROM MLP CROSS COUNTRY CRYO LINES. RUST COLORED WATER DELUGE IS SPRAYED ON THE MLP HYDROGEN SKID AREA. WATER FALLS FROM STIFFENER RINGS ON BOTH SRB'S AND VAPORIZES.

E-63
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views entire launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: RUST COLORED WATER IS SPRAYED ON THE MLP HYDROGEN SKID. SSME IGNITION IS NOMINAL, THOUGH HYDROGEN CONTINUES TO BURN IN THE FLAME TRENCH UNDER THE MLP. T-0 OCCURS AT FRAME 5515. SEVERAL PIECES OF ICE (7303 AND 7912) MAY HAVE ORIGINATED FROM THE ET/ORB UMBILICAL. WATER FROM THE RH SRB STIFFENER RINGS VAPORIZES. SLIDEWIRE BASKETS DID NOT RELEASE FROM SSME IGNITION THROUGH TOWER CLEAR. NO VEHICLE TPS ANOMALIES WERE VISIBLE.

E-64
96 FPS
35mm

Camera is located on NW pad perimeter at camera site 6 and views entire launch vehicle, FSS, and MLP.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER DELUGE SPRAY FROM THE FSS AND INTERTANK ACCESS ARM STRUCTURE IS BLOWN EAST TOWARD THE VEHICLE. T-0 OCCURS AT FRAME 5306. ICE ON THE MLP CROSS COUNTRY CRYO LINES IS SHAKEN LOOSE BY SRB IGNITION. TWO BIRDS FLY OUTWARD AWAY FROM THE VEHICLE. A THIRD ONE, MUCH CLOSER TO THE VEHICLE, FLIES NORTH, PASSES BETWEEN THE VEHICLE AND THE CAMERA, AND HEADS IN A SOUTHERLY DIRECTION. SEVERAL MORE BIRDS ENTER THE FIELD OF VIEW AFTER THE VEHICLE HAS CLEARED THE TOWER. WATER IN THE SRB STIFFENER RINGS FALLS AND VAPORIZES. ICE REMAINS ON THE -Y ET/SRB STRUT FITTING. SLIDEWIRE BASKETS DID NOT RELEASE FROM SSME IGNITION THROUGH TOWER CLEAR. SEVERAL PIECES OF FACILITY DEBRIS OR ICE ARE BLOWN WEST FROM THE MLP AS THE VEHICLE IS CLEARING THE TOWER.

E-65
100 FPS
16mm

Camera is located on east pad perimeter at camera site 2 and views ET LO2 feedline, ET intertank, and RH SRB as vehicle passes through the frame.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VISIBLE ORBITER/ET/SRB SURFACES SHOW NO SIGNS OF DAMAGE. SSV TWANG IS CLEARLY SEEN WITH T-0 AT FRAME 1012. ET TPS UNDER LOX FEEDLINE AND PRESSLINES LOOKS CLEAN. BIRD CROSSES FIELD OF VIEW JUST AFTER T-0 AT FRAME 1030. AS ET/ORB LH2 UMBILICAL PASSES (FRAME 1346), THE VAPOR AND ICE ACCUMULATION REMAINS VISIBLE AS A TRAILING CLOUD.

E-76
96 FPS
35mm

Camera is located on SE pad perimeter at camera site 3 and views SSME engines #1 and #3 and the RH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: SSME STARTUP (FRAME 261) CAUSES OSCILLATIONS IN SSME #1 AND #3 BEFORE PLUMES STABILIZE. AFT RCS PAPER COVERS TEAR AT FRAME 288. T-0 UMBILICAL DISCONNECT OCCURS AT 713. ICE/FROST PARTICLES FALL FROM ET/ORB LOX UMBILICAL.

E-77
96 FPS
35mm

Camera is located on SW pad perimeter at camera site 4 and views SSME engines #1 and #2 and the LH OMS engine nozzle.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: THREE PIECES OF LOOSE SRB THERMAL CURTAIN TAPE. ICE FALLS FROM LH2 T-0 UMBILICAL AFTER SSME START. LH2 T-0 UMBILICAL DISCONNECT IS NOMINAL. ICE FALLS FROM EO UMBILICALS. ICE FALLS FROM SSME'S DURING IGNITION AND SSME #1 AND #3 SHOW CONSIDERABLE MOVEMENT UNTIL PLUMES STABILIZE. RCS COVER PAPER RUPTURES. NO UNUSUAL DEBRIS IN THE EXHAUST CLOUD.

E-78
400 FPS
16mm

Camera is located on SE pad perimeter at camera site 3 and views RH OMS Pod leading edge.

Focus : SOFT
F. O. V.: TOO HIGH, SHOW MORE POD LEADING EDGE
Exposure: SLIGHTLY UNDEREXPOSED

Comments: ORBITER TPS IS INTACT AND UNDAMAGED AS VEHICLE RISES FROM FOV. ICE/FROST FALLS FROM THE ET/ORB LH2 UMBILICAL THRU EARLY ASCENT. FACILITY DEBRIS PASSES THROUGH FRAME AFTER VEHICLE LEAVES FOV. NO VEHICLE ANOMALIES OBSERVED.

E-79
100 FPS
16mm

Camera is located on east pad perimeter at camera site 2 and views the ET nosecone, louver, and ogive.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ET TIP DEFLECTION WAS MEASURED AT APPROXIMATELY 33 INCHES. A NORMAL LIGHT FROST LAYER IS EVIDENT ON THE +Y GOX VENT LOUVER. NO ET TPS ANOMALIES OBSERVED. ICE/FROST ACCUMULATION IS VISIBLE ON THE FORWARD SIDE OF THE ET LO2 FEEDLINE BRACKETS AT THE FEEDLINE INTERFACE. ICE/FROST AND DENSE VAPOR FALLS FROM ET/ORB LH2 UMBILICAL AREA AS VEHICLE RISES.

E-197 Cast Glance tracking of ET re-entry
35mm

Focus : SOFT - ATMOSPHERIC EFFECTS, AIRCRAFT MOTION
F. O. V.: TRACKING IS ERRATIC
Exposure: OK

Comments: TANK IS TUMBLING AS EXPECTED. A TRAIL OF ABLATING TPS IS VISIBLE FOLLOWING VEHICLE. MANY FRAGMENTS ARE VISIBLE AFTER LH2 TANK RUPTURE. TRACKING IS LOST FOR A LONG PERIOD OF TIME FOLLOWING LH2 TANK RUPTURE. LO2 TANK DOES NOT APPEAR TO RUPTURE VIOLENTLY, BUT RATHER SIMPLY BREAKS UP.

E-201 UCS-9 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: PARTICLES APPEAR FROM BEHIND THE ORBITER (FRAMES 412 - 419, 541-542, AND 753-756). SUN GLARE WASHES OUT DETAIL. NOMINAL SRB SEPARATION OCCURS AT FRAME 3786.

E-202 UCS-15 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: EARLY FLIGHT OBSCURED BY PLUME. A TOTAL OF 29 PARTICLES APPEAR BEHIND THE ORBITER DURING ASCENT BEGINNING AT FRAME 558. NO ANOMALIES NOTED. NOMINAL SRB SEPARATION IS AT FRAME 3905.

E-203 UCS-6 IFLOT tracking of launch vehicle from
30 FPS ignition and early flight through LOV.
70mm

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: PLUME GAS DYNAMICS OR BURNING DEBRIS FLASHES IN THE SSME PLUME (FRAMES 467, 530, 540). NO VEHICLE ANOMALIES. NOMINAL SRB SEPARATION AT FRAME 4034.

E-204
48 FPS
35mm

PAFB IGOR tracking of entire launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT - ATMOSPHERIC EFFECTS
F. O. V.: OK - SIMILAR TO ITEM E-212
Exposure: SLIGHTLY UNDEREXPOSED

Comments: PLUME RECIRCULATION PHENOMENON OCCURS AT EXPECTED TIME (FRAME 4455 - 5265). SRB BSM'S FIRE AT 5864. SLAG FALLS FROM BOTH SRB'S AFTER SEPARATION, BUT THERE ARE NO VEHICLE DEBRIS CONCERNS.

E-205
48 FPS
35mm

Shiloh IFLOT tracking of entire launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT - ATMOSPHERIC EFFECTS, CAMERA SHAKE
F. O. V.: VEHICLE MOSTLY OBSCURED BY PLUME
Exposure: SLIGHTLY UNDEREXPOSED

Comments: NO VEHICLE ANOMALIES OR DEBRIS CONCERNS.

E-206
48 FPS
35mm

Melbourne Beach ROTI tracking of entire launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SOFT - ATMOSPHERIC EFFECTS
F. O. V.: OK
Exposure: UNDEREXPOSED
Comments: PLUME RECIRCULATION PHENOMENON OCCURS AT THE EXPECTED TIME (FRAMES 3275 - 4065). SRB SEPARATION (4756) IS NOMINAL. NO DEBRIS CONCERNS.

E-207
96 FPS
35mm

UCS-10 MIGOR tracking of entire launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : OK
F. O. V.: EXCELLENT
Exposure: PROBABLY THE BEST POSSIBLE WITH A BACKLIT SUBJECT

Comments: PLUME CAUSES REFLECTIONS ON IEA'S AND UNDERSIDE OF OMS POD. SUNLIGHT REFLECTIONS OCCUR ON ORBITER NOSE AND ET NOSECONE. SHOCK WAVES FORM ON THE ORBITER FORWARD FUSELAGE AND RH SRB NOSE (762 - 2168). AT T+61 SECONDS, AN EVENT IS VISIBLE ON THE -Z SIDE OF THE ET. A SHOWER OF PARTICLES OR PUFF OF VAPOR ORIGINATES NEAR THE ET INTERTANK AREA AND FOLLOWS THE AERODYNAMIC STREAMLINES AFT UNTIL IT EXPANDS/DISSIPATES NEAR THE 2058 RING (FRAME 2996 - 3002). SLAG DROPS FROM THE RH SRB NOZZLE AFTER SEPARATION.

E-208
48 FPS
35mm

Cocoa Beach DOAMS tracking of entire launch vehicle from acquisition to SRB separation. Tracks ET/ORB after SRB separation to LOV.

Focus : SLIGHTLY SOFT ATMOSPHERIC EFFECTS
F. O. V.: OK
Exposure: OK

Comments: NO VEHICLE ANOMALIES OR DEBRIS CONCERNS. RECIRCULATION PHENOMENON OF PLUME OCCURS AT THE EXPECTED TIME (FRAME 2895 - 3563).

E-209
30 FPS
70mm

UCS-13 IFLOT intermediate tracking of launch vehicle from acquisition to LOV.

Focus : SOFT
F. O. V.: OK
Exposure: OK

Comments: VEHICLE ACQUIRED LATE AT ABOUT FRAME 246. NOMINAL SRB SEPARATION AT FRAME 3903. NO VEHICLE ANOMALIES.

E-210
30 FPS
70mm

UCS-26 IFLOT intermediate tracking of launch vehicle from acquisition to LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: VEHICLE ACQUIRED LATE AT ABOUT FRAME 390. NOMINAL SRB SEPARATION AT FRAME 3705. NO VEHICLE ANOMALIES.

E-211 UCS-13 IFLOT intermediate tracking of forward portion of ORB and ET from acquisition to LOV.
96 FPS
35mm

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS
F. O. V.: OK
Exposure: UNDEREXPOSED
Other : CAMERA AZIMUTH NOT IN LINE WITH THE LAUNCH PAD DELAYED ACQUISITION.

Comments: MINIMAL AFT DOME CHARRING EXCEPT ON THE MANHOLE COVER. A SHOWER OF SMALL PARTICLES OR PUFF OF VAPOR ON THE -Z SIDE OF THE ET APPEARS TO ORIGINATE NEAR THE INTERTANK AREA, POSSIBLY THE GUCP OR LH2 TANK FLANGE AT FRAME 4082, T+61 SECONDS (SEE ITEM E-207). THE PHENOMENON, WHICH IS BACKLIT BY THE SUN, EXPANDS AND BEGINS TO DISSIPATE NEAR THE 2058 RING AT FRAME 4091. SHOCK WAVE HAS DISAPPEARED BY FRAME 3195.

E-212 UCS-23 MIGOR tracking of launch vehicle from acquisition to LOV.
96 FPS
35mm

Focus : SOFT - ATMOSPHERIC EFFECTS
F. O. V.: EXCELLENT, GOOD TRACKING
Exposure: SLIGHTLY UNDEREXPOSED
Other : MANY SMALL FILM DEFECTS - GIVES APPEARANCE OF DEBRIS

Comments: AERODYNAMIC SHOCK WAVE FORMS ON ORBITER FWD FUSELAGE AND SRB FORWARD ASSEMBLY AT FRAME 2780. STRAIGHT LINE OPTICAL OR FILM DEFECT STARTS AT ORBITER MID-BODY, PASSES BY TAIL AND INTO PLUME AT FRAME 4318. MANHOLE COVER ON ET AFT DOME HAS SUSTAINED LIGHT CHARRING.

E-213 UCS-7 MOTS tracking of forward portion of ORB and ET from acquisition to LOV.
96 FPS
35mm

Focus : OK
F. O. V.: TRACKING VERY ERRATIC
Exposure: OK

Comments: TWO PIECES OF DEBRIS APPEAR UNDER LH WING (1170). RH RCS PAPER COVERS FALL OFF VEHICLE (FRAME 1410) WITH THE LH RCS COVERS FOLLOWING AT FRAME 1641.

E-214 UCS-15 IFLOT close-in tracking of launch
32 FPS vehicle during ignition, liftoff, and early
16mm portion of flight through LOV.

Focus : SLIGHTLY SOFT - ATMOSPHERIC EFFECTS
F. O. V.: OK, BUT TRACKING IS UNSTEADY
Exposure: SLIGHTLY UNDEREXPOSED

Comments: LIFTOFF IS OBSCURED BY SSME PLUME. WATER FROM SRB STIFFENER RINGS VAPORIZES. AERODYNAMIC SHOCK WAVE FORMS ON ORBITER FWD FUSELAGE AND SRB FWD ASSEMBLY. SRB SEPARATION IS NOMINAL. SOME SLAG DROPS FROM SEPARATED BOOSTERS.

E-215 UCS-9 IFLOT close-in tracking of launch
32 FPS vehicle during ignition, liftoff, and early
16mm portion of flight through LOV.

Focus : SOFT
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: SUN'S GLARE PREVENTS MUCH DETAIL FROM BEING DISCERNIBLE. CONDENSATE ON ET AFT DOME AND WATER FROM SRB STIFFENER RINGS VAPORIZES. SHOCK WAVE IS MORE VISIBLE DUE TO BACKLIGHTING CONDITION.

E-216 UCS-6 IFLOT close-in tracking of launch
48 FPS vehicle during ignition, liftoff, and early
16mm portion of flight through LOV.

Focus : SOFT - ATMOSPHERIC EFFECTS
F. O. V.: OK
Exposure: UNDEREXPOSED

Comments: BIRD CROSSES FOV WHILE VEHICLE IS IN ROLL MANEUVER. WATER FROM SRB STIFFENER RINGS AND CONDENSATE ON ET AFT DOME BEGIN TO VAPORIZE. UNUSUAL PERSPECTIVE OF AERODYNAMIC SHOCK WAVE AROUND THE SRB FORWARD ASSEMBLIES AND ON THE ET/SRB FORWARD CROSSOVERS. THE SHOWER OF PARTICLES OR PUFF OF VAPOR EVENT ON THE -Z SIDE OF THE ET (SEE ITEMS E-207 AND E-211) IS BARELY VISIBLE (FRAMES 3055-3070).

E-217 Beach Road IFLOT close-in tracking of launch
30 FPS vehicle during ignition, liftoff, and early
70mm portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: MORE THAN 100 BIRDS PASS BETWEEN THE CAMERA AND THE VEHICLE, BUT NONE STRIKE THE VEHICLE. SHORTLY AFTER ROLL PROGRAM (FRAME 570) A PARTICLE APPROXIMATELY 8-12" MAJOR DIMENSION AND ORANGE IN COLOR FALLS OVER RH ORBITER WING AND CONTINUES INTO THE PLUME. THE ORIGIN THIS PARTICLE MAY BE THE RH FWD RCS. A PARTICLE ORANGE/RED IN COLOR AND 6-8" MAJOR DIMENSION FALLS UNDERNEATH THE ORBITER BETWEEN THE SRB'S (624). THE AFT DOWN-FIRING LH NOSE RCS THRUSTER PAPER COVER COMES OFF (644). A PARTICLE OF 12-14" MAJOR DIMENSION FALLS FROM BEHIND THE BODY FLAP (653). AT FRAME 737, TWO PARTICLES COME FROM BEHIND THE LH INBOARD ELEVON (2-3" AND 4-6"). ONE PARTICLE IS BEHIND ELEVONS (744), AND ANOTHER BEHIND THE VERTICAL STABILIZER. AT FRAME 745 TWO PARTICLES ARE BEHIND THE VERTICAL STABILIZER. A PARTICLE IS BEHIND THE LH INBOARD ELEVON (749). AT FRAME 831, A LH FWD RCS PAPER COVER COMES OFF AND APPEARS UNDER THE ET (837) - MAY BE ABOUT 12" MAJOR DIMENSION. AT FRAME 843, ANOTHER LH FWD RCS COVER PAPER COMES OFF AND PASSES UNDER THE ET (848). AT FRAME 896 A LARGE PARTICLE IS VISIBLE BEHIND THE ET. THE MIDDLE FWD NOSE RCS PAPER COVER COMES OFF (907). AT FRAME 916 THIS PAPER IS AFT OF THE SSME'S. AT FRAME 944 THE -Y FWD NOSE RCS PAPER COVER COMES OFF, CROSSES OVER THE LH WING, AND PASSES BENEATH THE ET. AT FRAMES 998 AND 1089, PARTICLES ARE VISIBLE BENEATH THE ET. THE FWD DOWN-FIRING LH NOSE RCS COVER PAPER COMES OFF (1113). TWO PARTICLES PASS BENEATH THE ET (1117) FOLLOWED BY ANOTHER AT FRAME 1166. AT FRAME 1178, TWO PARTICLES APPEAR UNDER THE RH ELEVONS.

E-218 UCS-26 IFLOT intermediate tracking of launch
96 FPS vehicle from acquisition through LOV.
35mm

Focus : SOFT DUE TO ATMOSPHERIC
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED
Other : FIRST FRAME NOT IDENTIFIED
Comments: AERODYNAMIC SHOCK WAVE FORMS ON VEHICLE. RECIRCULATION PHENOMENON OCCURS AT EXPECTED TIME. SRB SEPARATION IS NOMINAL AND SOME PIECES OF SLAG FALL FROM SRB NOZZLES.

E-219 UCS-3 IFLOT close-in tracking of launch
30 FPS vehicle during ignition, liftoff, and early
70mm portion of flight through LOV.

Comments: NOT RUN FOR STS-29R DUE TO EQUIPMENT SHORTAGE.

E-220 UCS-15 IFLOT close-in tracking of launch
96 FPS vehicle during ignition, liftoff, and early
35mm portion of flight through LOV.

Focus : SOFT DUE TO ATMOSPHERIC EFFECTS
F. O. V.: EXCELLENT TRACKING DURING EARLY ASCENT, ERRATIC LATER IN FLIGHT
Exposure: OK

Comments: PAPER COVER FROM THE LH FWD RCS PITCH THRUSTER COMES OFF AT FRAME 2228 FOLLOWED BY ANOTHER AT FRAME 2814 AND STILL TWO MORE AT FRAME 2847. COVERS FROM RCS THRUSTER ON ORBITER NOSE +Z SIDE COME LOOSE AT FRAME 3165. ONE COVER FROM THE LH RCS SEPARATES AT FRAME 3689. AERODYNAMIC SHOCK WAVE (FRAME 3949 - 5010) FORMS ON ORBITER FWD FUSELAGE AND SRB. REFLECTION ON LH WING TIP OCCURS AT FRAME 5010. AT T+61 SECONDS, AN EVENT IS VISIBLE ON THE -Z SIDE OF THE ET. A SHOWER OF PARTICLES OR PUFF OF VAPOR ORIGINATES NEAR THE ET INTERTANK AREA, FOLLOWS THE AERODYNAMIC STREAMLINES AFT, AND EXPANDS/DISSIPATES NEAR THE 2058 RING FRAME (FRAME 6180 THRU 6192). ON-ORBIT FLIGHT CREW PHOTOGRAPHY OF THE ET REVEALED THAT THREE PIECES OF ACREAGE FOAM WERE LOST FROM THE INTERTANK -Y-Z THRUST PANEL. THESE PIECES OF MISSING FOAM ARE CONSIDERED THE MOST LIKELY SOURCE OF THE EVENT NOTED, BUT THE EVENT SOURCE COULD ALSO HAVE BEEN ICE/FROST FROM THE GUCP OR THE LH SRB -Z RSS ANTENNA TPS RAMP.

E-221 UCS-3 IFLOT close-in tracking of forward portion
96 FPS of ORB and ET during ignition, liftoff, and early
35mm portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER IN THE SRB STIFFENER RINGS VAPORIZES. ONE BIRD FLIES IN THE VICINITY OF THE RH WING (FRAME 305) WITH NO VEHICLE IMPACT. ANOTHER BIRD IS NEAR THE LIGHTNING ROD (FRAME 400). NO BIRDS VISIBLE IN THE TIME FRAME JUST PRIOR TO ROLL MANEUVER (T+9 SECONDS). NO DEBRIS COMES OFF THE AFT END OF THE SRB. SHOCK WAVE ON THE ORBITER FORWARD FUSELAGE AND SRB BEGINS AT FRAME 2700 AND

CONTINUES UNTIL FRAME 3405. AFT DOME CHARRING WAS MINIMAL. FLASHES ASSOCIATED WITH GAS DYNAMIC EFFECT ARE LESS THAN PREVIOUS MISSIONS.

E-222 Beach Road IFLOT close-in tracking of forward
96 FPS portion of ORB and ET during ignition, liftoff,
35mm and early portion of flight through LOV.

Focus : OK
F. O. V.: OK, GOOD EARLY TRACKING
Exposure: OK

Comments: AS MANY AS 100 BIRDS ARE IN THE PAD AREA AT LAUNCH, BUT NONE STRIKE THE VEHICLE. AERODYNAMIC SHOCK WAVE OCCURS FROM FRAME 3585 THRU 4215. VERY GOOD VISIBILITY OF FWD RCS THRUSTER PAPER COVERS SEPARATING FROM THE VEHICLE:

RH SIDE	SEPARATES 1876		AFT END OF VEHICLE	1901
	2430		2447	
	2461		2480	
	3270		3284	
TOP	2657		2679	
	2752		2765	
LH SIDE		2768		2784
	2961		2980	

WHITE MATERIAL PASSES OVER INBOARD ELEVON AT FRAME 2809.

E-223 UCS-9 IFLOT intermediate tracking of forward
96 FPS portion of ORB and ET during ignition, liftoff,
35mm and early portion of flight through LOV.

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: WATER FROM SRB STIFFENER RINGS AND CONDENSATE FROM ET AFT DOME VAPORIZES. SUNLIGHT CAUSES REFLECTIONS ON THE ORBITER NOSE, RH SRB NOSECONE, AND ET NOSECONE. REFLECTIONS FROM THE SRB PLUME OCCUR ON THE SRB IEA'S AND THE UNDERSIDE OF THE OMS POD. SHOCK WAVE IS VISIBLE ON THE ORBITER FORWARD FUSELAGE AND THE ET/SRB FORWARD CROSSOVER.

STARCAST Airborne tracking of entire launch vehicle
16mm

Focus : SOFT
F. O. V.: TRACKING ERRATIC

Exposure: SLIGHTLY UNDEREXPOSED

Comments: FILM ENDS PRIOR TO SRB SEPARATION. NO VEHICLE ANOMALIES

STARCAST Airborne tracking of entire launch vehicle
35mm

Focus : OK
F. O. V.: OK
Exposure: SLIGHTLY UNDEREXPOSED

Comments: SRB SEPARATION IS NORMAL. NO VEHICLE ANOMALIES.

T-MAX Airborne tracking of entire launch vehicle
35mm

Focus : OK
F. O. V.: TRACKING ERRATIC
Exposure: OK
Other : FILM HAS MANY DEFECTS AND IS GRAINY

Comments: SRB SEPARATION IS NORMAL. NO VEHICLE ANOMALIES.

HIGH ALTITUDE Airborne tracking of entire launch vehicle

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: ONLY 4 FRAMES OF THIS ITEM CONTAIN AN IMAGE OF THE LAUNCH VEHICLE. NO VEHICLE ANOMALIES.

E-233 SRB reentry
35mm

Focus : OK
F. O. V.: OK
Exposure: OK

NOZZLE EXTENSION IS ALREADY SEVERED AND AFT BOOSTER DARKENED AT ACQUISITION. FLAME IS VISIBLE UNDER AFT SKIRT. "CHUFFING" EVIDENT ALMOST ALL THE WAY TO SPLASHDOWN. PARACHUTE DEPLOYMENT NORMAL. NOSECAP AND FRUSTRUM SEPARATION APPEAR NORMAL. NO DEBRIS CONCERNS.

E-234 SRB reentry
35mm

Focus : SOFT - ATMOSPHERIC EFFECTS
F. O. V.: TROUBLE WITH ERRATIC ACQUISITION AND TRACKING
Exposure: GENERALLY UNDEREXPOSED

Comments: NOZZLE EXTENSION IS ALREADY SEVERED AND AFT BOOSTER DARKENED AT ACQUISITION. FLAME IS VISIBLE UNDER AFT SKIRT AND "CHUFFING" OCCURS ALMOST ALL THE WAY TO SPLASHDOWN. PARACHUTE DEPLOYMENT NORMAL. NOSECAP AND FRUSTUM SEPARATION NOT VISIBLE DUE TO TRACKING PROBLEMS. NO DEBRIS CONCERNS.

E-301 RH SRB Parachute deployment
200 FPS
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: DEBRIS, ROLL OF TAPE, AND LOOSE PARACHUTE RESTRAINT CORD ARE VISIBLE AS PARACHUTES DEPLOY. SMOKE IS FROM CHUFFING OF SRM'S. SMALL PIECES OF BURNING MATERIAL FROM AFT END OF BOOSTER TRAILING SMOKE STREAMERS APPEAR IN FOV WHILE PARACHUTES ARE REEFING. NO APPARENT DAMAGE TO PARACHUTES.

E-302 LH SRB Parachute deployment
200 FPS
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: DEBRIS AND LOOSE PARACHUTE RESTRAINT CORD APPEAR AS PARACHUTES DEPLOY. SOME SMOKE IS VISIBLE FROM CHUFFING OF SRM'S. SMALL PIECES OF BURNING MATERIAL FROM AFT END OF BOOSTER TRAILING SMOKE STREAMERS APPEAR IN FOV WHILE PARACHUTES ARE REEFING.

ALTHOUGH ONE PARACHUTE NEARLY COLLAPSES AND THEN REOPENS JUST PRIOR TO REEFING, NO DAMAGE IS VISIBLE TO ANY OF THE THREE CHUTES.

E-425 Orbiter crew compartment window #4 camera. Views
16mm portions of FRCS and ET LO2 tank ogive.
Focus : SOFT
F. O. V.: OK
Exposure: OK
Comments: RCS BUTCHER PAPER COVER STARTS TO FLAP (FRAME 1380). SOME RELATIVE MOTION OCCURS BETWEEN THE ET AND ORBITER AT SRB IGNITION. THROUGHOUT THE FILM, NUMEROUS SMALL PARTICLES OF DEBRIS PASS THROUGH THE FOV. SOME ARE VISIBLE FOR ONLY ONE FRAME. MOST ARE RCS PAPER COVERS, BUT SOME PROBABLY ORIGINATE FROM OTHER SOURCES. A THIN OBJECT (FRAME 2120), PERHAPS A BEAD OF RTV, PASSES THROUGH FOV. LARGE PIECES OF RCS PAPER COVERS TEAR LOOSE FROM THE RCS NOZZLES IN FRAMES 3040, 3690, AND 4597. A LARGE PIECE OF BUTCHER PAPER PULLS FREE FROM THE CENTER +Z RCS NOZZLE (FRAME 4810) AND HITS WINDOW #4 (FRAME 4815), LEAVING A LARGE STREAK OF RTV. THE +Z SIDE ET LO2 TANK OGIVE TPS APPEARS TO REMAIN INTACT THROUGHOUT ASCENT. SRB SEPARATION IS NORMAL. PILOT'S WINDOW #4 IS HAZED BY THE BSM PLUME. AN UNKNOWN DARK OBJECT IS VISIBLE IN THE UPPER RH FRAME DURING SRB SEPARATION.

ON-ORBIT Still views from hand held camera of ET after
70mm separation from Orbiter

Focus : OK
F.O.V. : OK
Exposure: OK

Comments: Most of the External Tank was in good condition. No divots were visible in the LO2 and LH2 tank acreage areas. The nosecone, PAL ramps, RSS antennae, flight door, and LO2 feedline exhibited no problem. The bipods, LO2 feedline fairing, thrust struts, and crossbeam were scorched from ascent aeroheating - an expected occurrence. The ogive TPS was slightly eroded from the BSM plume impingement and the surrounding TPS was scorched and covered by BSM deposits. However, the spray pattern of the underlying TPS was still visible.

The TPS in the area of the 2-foot crack in the intertank stringer previously identified prior to launch was intact. The repair to the -Y thrust panel just forward of the SRB attach point was also intact. Bright areas on the LO2 tank pressurization line ramps are caused by reflections on the sanded surfaces. The two bright

areas on the LH2 tank acreage near the +Y longeron are also sanded TPS. And the divot-like spot on the Intertank above the bipods is the attach point for the bipod installation fixture.

Anomalies on the External Tank include a 6-inch divot on the +Y longeron where a previous vendor repair existed. Four TPS divots, two of which are at least 14 inches in diameter, are visible along the edges of the -Y thrust panel. Two 6-inch and numerous smaller divots are present at the intertank to LO2 tank interface. At least 7 divots are visible behind the bipods and along the intertank to LH2 flange on the -Y side of the bipod area. Along the LH2 tank to intertank flange and acreage ramp on the +Y side of the LO2 feedline near the thrust panel, 3 large divots measuring 15, 18, and 20 inches in diameter, have occurred. As many as 7 more smaller divots are present on the flange closeout in the direction of the thrust panel. In addition, the bipods did not fold up against the tank as designed.

E-1001 Orbiter Landing at DFRF
16mm

Focus : SOFT
F. O. V.: OK, BUT CLAPBOARD IMAGE IS VISIBLE ON FILM UNTIL AFTER LANDING GEAR DEPLOYMENT
Exposure: OK

Comments: NO VEHICLE ANOMALIES. VEHICLE PASSES BEHIND A BUILDING AT MLG TOUCHDOWN. ROLLOUT IS NORMAL.

E-1002 Orbiter Landing at DFRF
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NO VEHICLE ANOMALIES. LANDING GEAR DEPLOYMENT IS NOMINAL.

E-1005 Orbiter Landing at DFRF
16mm

Focus : SLIGHTLY SOFT
F. O. V.: OK
Exposure: OK

Comments: NO VEHICLE ANOMALIES. APPROACH, LANDING GEAR DEPLOYMENT, TOUCHDOWN, AND ROLLOUT NOMINAL.

E-1006 Orbiter Landing at DFRF
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NO VEHICLE ANOMALIES. APPROACH, LANDING GEAR DEPLOYMENT, TOUCHDOWN, AND ROLLOUT NOMINAL.

E-1008 Orbiter Landing at DFRF
16mm

Focus : OK
F. O. V.: OK
Exposure: ONE STOP UNDEREXPOSED

Comments: NO VEHICLE ANOMALIES. APPROACH, LANDING GEAR DEPLOYMENT, TOUCHDOWN, AND ROLLOUT NOMINAL.

E-1009 Orbiter Landing at DFRF
16mm

Focus : OK
F. O. V.: OK
Exposure: OK

Comments: NO VEHICLE ANOMALIES. APPROACH, LANDING GEAR DEPLOYMENT, TOUCHDOWN, AND ROLLOUT NOMINAL.

E-1012 Orbiter Landing at DFRF
16mm

Focus : OK
F. O. V.: VEHICLE TOO LOW IN FRAME
Exposure: OK

Comments: NO VEHICLE ANOMALIES. VEHICLE IS NOT ACQUIRED UNTIL AFTER LANDING GEAR DEPLOYMENT. MOST OF THE ROLLOUT IS OBSCURED BY PERSONNEL AND VEGETATION.

VIDEO ITEMS

OTV 101 Views aft end of Orbiter from the FSS 255 foot
B/W M-II level.

Comments: SSME FLAME HOLE DELUGE WATER BEGINS AT T-14 SECONDS. SIMULTANEOUSLY, ORBITER VENT DOORS #8 AND 9 MOVE FROM PARTIAL TO FULL OPEN POSITION. TYPICAL ICE ACCUMULATION ON LH2 T-0 8-INCH LINE PURGE BOX. T-O SEPARATION AND RETRACTION APPEARS NORMAL. SOME LH2 VAPORIZES AS CARRIER PLATE IS RETRACTED. NO VEHICLE ANOMALIES.

OTV 103 Views GUCP and GH2 vent line.
B/W M-II

Comments: WISPY VAPORS ARE VENTED FROM GUCP AREA PRIOR TO IGNITION. FSS WATER DELUGE PARTIALLY OBSCURES VIEW. VEHICLE TWANG IS VISIBLE. GUCP SEPARATION AND GH2 VENT ARM RETRACTION ARE NOMINAL. SOME GH2 VENT FROM GUCP AS ARM IS RETRACTED. NO VEHICLE ANOMALIES. A FEW PIECES OF FACILITY DEBRIS ENTER FRAME AFTER VEHICLE LEAVES FOV.

OTV 109 Views ET/Orbiter LH2 umbilical area from the 95
B/W M-II foot level of the FSS.

Comments: ROFI IGNITION, SSME IGNITION, AND LIFTOFF ALL APPEAR NOMINAL. DENSE VAPORS FROM LH2 T-0 UMBILICAL ARE DRAWN DOWNWARD BY SSME IGNITION. NO VEHICLE ANOMALIES.

OTV 111 Views GUCP and GH2 vent line with new Insight IR
B/W IR camera.

Comments: CAMERA IS TURNED AWAY FROM VEHICLE DURING IGNITION AND LIFTOFF. NO USEFUL DATA.

OTV 119 Views LH2 umbilical with new Insight IR camera.
B/W IR

Comments: CAMERA IS TURNED AWAY FROM VEHICLE DURING IGNITION AND LIFTOFF. NO USEFUL DATA.

OTV 130 Views SSMEs and Orbiter aft end from SE pad apron
B/W IR with new Insight IR camera.

Comments: CAMERA IS TURNED TOWARD FSS. VIEWS SSME PLUME, BUT IS STILL OVERDRIVEN. NO USEFUL DATA.

OTV 134 Views MLP side 1 (south) LH2 skid.
B/W

Comments: CAMERA WAS NOT POINTED AT VEHICLE DURING LIFTOFF.

OTV 135 Views base of the FSS.
B/W

Comments: CAMERA WAS NOT POINTED AT VEHICLE DURING LIFTOFF.

OTV 141 Views and tracks vehicle from camera site 2.
B/W

Comments: FSS WATER DELUGE BEGINS AT T-13 SECONDS. VEHICLE TWANG IS VISIBLE. AT T+13 SECONDS, SUNLIGHT IS REFLECTED ON THE GOX PRESSURIZATION LINE. BRIGHT SPOTS NEAR ORBITER LH FUSELAGE AT T+18 SECONDS ARE LENS FLARE.

OTV 143 Views east side of launch vehicle and pad from
B/W camera site 2.

Comments: VAPORS STILL EMANATE FROM ET/ORB LH2 UMBILICAL AFTER LIFTOFF. WATER FROM SRB STIFFENER RINGS VAPORIZES. NO VEHICLE ANOMALIES. BIRD CROSSES FOV FROM RIGHT TO LEFT AT T+6 SECONDS.

OTV 148 Launch and tracking view from camera site 6.
B/W

Comments: BIRD CROSSES LOWER LEFT CORNER OF FRAME AT T+1 SECOND, BUT NO CONTACT OCCURS WITH VEHICLE. TRACKING IS ERRATIC. NO VEHICLE ANOMALIES.

OTV 149 Views Orbiter LO2 T-0 umbilical from MLP deck.
B/W M-II

Comments: AT T-5 SECONDS, SSME STARTUP HAD BEEN INITIATED, RCS THRUSTER PAPER COVERS TEAR, AND ICE/FROST PARTICLES FALL FROM LOX T-0 UMBILICAL. LARGE QUANTITIES OF GOX ARE DRAWN INTO SSME PLUME AS THE LOX CARRIER PLATE SEPARATES FROM THE ORBITER. SEPARATION AND RETRACTION OF THE T-0 UMBILICAL IS NOMINAL. TWO PARTICLES OF ICE FROM THE ET/ORB LOX UMBILICAL FALL INTO VIEW FROM BEHIND BODY FLAP AT T+1 SECOND. NO VEHICLE ANOMALIES.

OTV 150 Views Orbiter LH2 T-0 umbilical from SW MLP deck.
B/W M-II

Comments: ICE/FROST HAS ACCUMULATED ON LH2 T-0 UMBILICAL PURGE BOX INTERFACE. SSME CAUSES SEVERAL PIECES OF ICE/FROST TO SHAKE LOOSE. A 4-INCH PIECE OF TAPE ON THE LOWER PART OF THE UMBILICAL IS LOOSE AND FLAPPING. UMBILICAL SEPARATION AND RETRACTION IS NOMINAL. A SMALL QUANTITY OF VAPOR EMANATES FROM ORBITER DISCONNECT AS VEHICLE RISES.

OTV 151 Views main engine cluster.
B/W M-II

Comments: SSME IGNITION IS NOMINAL. RCS PAPER COVERS RUPTURE DURING SSME STARTUP. NO APPARENT DAMAGE TO AFT HEATSHIELD TILES OR RH OMS NOZZLE. LOX T-0 UMBILICAL SEPARATION AND RETRACTION IS NORMAL. LARGE QUANTITY OF GOX IS RELEASED AT SEPARATION. LH2 TSM DOOR IS CLOSED BEFORE VEHICLE PASSES. MANY PIECES OF FACILITY DEBRIS CROSS FOV AFTER VEHICLE HAS CLEARED FRAME.

OTV 154 Views ET/Orbiter LO2 umbilical and Orbiter RH wing
B/W M-II

Comments: DENSE VAPORS EMANATE FROM ET/ORB LH2 UMBILICAL PRIOR TO SSME IGNITION. VAPORS DO NOT GREATLY INCREASE DURING PRESSURIZATION TO FLIGHT PRESSURE (STARTING AT T- 1M 47S), BUT DO INCREASE AFTER SSME IGNITION. A FEW PARTICLES OF ICE/FROST FALL FROM ET/ORB LOX UMBILICAL AND A LARGE QUANTITY OF VAPOR/ICE PARTICLES FALL FROM ET/ORB LH2 UMBILICAL DURING SSME IGNITION.

OTV 155 Views RH SRB and underside of Orbiter RH wing.
B/W M-II

Comments: CAMERA HAS EXPOSURE AND SYNC PROBLEMS. SSME IGNITION IS NOMINAL. DENSE VAPORS EMANATE FROM ET/ORB LH2 UMBILICAL DURING SSME IGNITION. DELUGE WATER FROM MLP DECK RAINBIRDS BEGINS ON TIME PRIOR TO SRB EXHAUST IMPINGEMENT.

OTV 156 Views LH SRB and underside of Orbiter LH wing.
B/W M-II

Comments: SSME IGNITION IS NOMINAL. DENSE VAPORS EMANATE FROM ET/ORB LH2 UMBILICAL DURING SSME STARTUP. ONE PIECE OF THERMAL CURTAIN TAPE HAS COME LOOSE ON THE RH SRB.

OTV 160 Views ET nosecone and NE louver from water tower.
Color M-II

Comments: HEAVY FALL OF ICE/FROST PARTICLES FROM ET/ORB LH2 UMBILICAL AT LIFTOFF. GH2 VENT ARM LATCHES PROPERLY. NO SRB ANOMALIES.

OTV 161 Views ET nosecone and SW louver from the FSS.
Color M-II

Comments: NO ET FAIRING ANOMALIES. NO ICE BALLS IN THE LOUVERS, BUT FROST IS PRESENT ON THE NORTHERN THIRD OF THE SW LOUVER. SMALL PIECE OF FROST OR SLA COMES LOOSE AT T-0 JUST BELOW THE LOUVER'S EDGE AND IS BLOWN SOUTH. MATERIAL IN AREA OF REFLECTION AT XT-371 (HALF WAY BETWEEN FAIRING AND LOUVER) APPEARS RAISED AND MOVES WITH SSME IGNITION - MAY BE DELAMINATED TOPCOAT. NO SRB ANOMALIES. MANY FROST PARTICLES FALL FROM ET/ORB LH2 UMBILICAL, BUT NO ORBITER TILE DAMAGE IS VISIBLE. WATER TROUGH AND SRB THROAT PLUG MATERIAL FLY THROUGH FRAME AFTER VEHICLE CLEARS TOWER.

OTV 163 Views ET/Orbiter umbilical and Orbiter T-0
Color M-II umbilical from the FSS.

Comments: WATER DELUGE PASSES THROUGH FRAME PRIOR TO LIFTOFF. SHOWER OF LIQUID AIR AND ICE/FROST PARTICLES FALL FROM ET/ORB LH2 UMBILICAL , BUT NO DAMAGE TO ORBITER TILES IS VISIBLE. THREE PIECES OF THERMAL CURTAIN TAPE HAVE COME LOOSE ON THE RH SRB. A

PIECE OF INSTAFOAM HAS SEPARATED FROM THE AFT SKIRT NEAR HDP #1. ROFI SPARKS BLOW UNDER BODY FLAP AND FALL TO MLP DECK. K5NA CLOSEOUT ON LH SRB IEA COVER IS INTACT.

OTV 170 Views overall vehicle from SE direction.
Color M-II

Comments: RUST-COLORED DELUGE WATER IS SPRAYED ON MLP LH2 SKID. SSME IGNITION IS NOMINAL. WATER FROM THE RH SRB STIFFENER RINGS VAPORIZES.

OTV 171 Views overall vehicle from SW direction.
Color M-II

Comments: AFT RCS PAPER COVERS TEAR AT T-0 AND A COVER FROM THE LH STINGER COMES OFF AS VEHICLE RISES. A SHOWER OF ICE/FROST PARTICLES FALL FROM ET/ORB LH2 UMBILICAL. FROST IS SHAKEN LOOSE AND FALLS FROM ENGINE MOUNTED HEAT SHIELDS. THE LH2 T-0 UMBILICAL SEPARATION AND RETRACTION IS NORMAL. A PIECE OF DEBRIS RISES OUT OF THE FLAME TRENCH AFTER THE VEHICLE HAS CLEARED THE MLP.

OTV 172 Views SSMEs with new Insight IR camera from SW
B/W IR corner of MLP deck.

Comments: CAMERA IS TURNED TOWARD CRAWLERWAY. VIEWS SSME PLUME, BUT IS OVERDRIVEN BY SRB PLUME. NO USEFUL DATA. A FEW PIECES OF FACILITY DEBRIS CROSS FOV AFTER LIFTOFF.

STI (C/S 2) Infrared view from camera site 2.
B/W M-II

Comments: SSME IGNITION APPEARS NOMINAL. WESTERLY WIND CAUSES BURNING HYDROGEN TO RISE BRIEFLY HALF WAY UP THE VERTICAL STABILIZER ON THE SOUTH SIDE, AND AS HIGH AS THE AFT HEATSHIELD ON THE NORTH SIDE OF THE TSM. AS THE SSME PLUME BEGINS TO STABILIZE PRIOR TO LIFTOFF, THE CAMERA LOOSES SIGNAL SYNCHRONIZATION DUE TO A LOOSE CABLE CONNECTOR IN THE CAMERA ASSEMBLY.

STI (RSS) Infrared view from RSS roof.
B/W M-II

Comments: SSME IGNITION APPEARS NORMAL. NO UNUSUAL BURNING OF EXCESS HYDROGEN - MAY HAVE BEEN BLOWN EASTWARD BY WIND.

TV-1 Views launch from SLF convoy.
Color M-II

Comments: TOO DISTANT FOR CLOSE-IN DETAIL. NO PLUME ANOMALIES.

TV-2 Views launch from SLF midfield.
Color M-II

Comments: TOO DISTANT FOR CLOSE-IN DETAIL. NO PLUME ANOMALIES.

TV-3 Views entire launch vehicle from UCS-9
Color M-II

Comments: VIEW IS BACKLIT AND THEN LOST IN SUN'S GLARE. NO VEHICLE ANOMALIES.

TV-4 Views entire vehicle from Beach Road IFLOT Site.
Color M-II

Comments: SSME IGNITION IS NORMAL AND NO VEHICLE ANOMALIES THRU TOWER CLEAR. WATER FROM SRB STIFFENER RINGS AND CONDENSATE ON ET AFT DOME VAPORIZE. AT T+8 SECONDS JUST PRIOR TO ROLL PROGRAM, MANY BIRDS ENTER FIELD OF VIEW. ALTHOUGH A BIRD APPEARS TO STRIKE THE ORBITER RH WING, OTHER CAMERA VIEWS CONFIRM NO BIRD CAME CLOSE ENOUGH FOR CONTACT. THIS PARTICULAR BIRD WAS BETWEEN THE VEHICLE AND THE CAMERA AND ITS EVASIVE ACTION GAVE THE APPEARANCE OF AN IMPACT DEFLECTION. AT T+15 SECONDS, A BIRD NEAR THE CAMERA CROSSES FRAME FROM LEFT TO RIGHT. AERODYNAMIC SHOCK WAVE EXPANSION HAS FORMED ON THE ORBITER FORWARD FUSELAGE AT T+47 SECONDS. ALL VISIBLE ET TPS IS STILL INTACT.

TV-5 Views launch from VAB roof.
Color M-II

Comments: LOSS OF DATA DUE TO TRACKING PROBLEMS.

TV-6 Views entire launch vehicle from DLTR-3 site
Color M-II directly south of Pad B.

Comments: VEHICLE IS OBSCURED BY SSME PLUME UNTIL CLEAR OF THE TOWER. JUST AFTER FSS CLEAR, A LARGE BIRD PASSES BETWEEN THE PLUME AND THE CAMERA, TURNS INTO THE PLUME, AND DOES NOT REAPPEAR. VEHICLE IS ALREADY TOO FAR AWAY FOR POSSIBLE CONTACT. AT T+9 SECONDS, TWO MORE BIRDS APPEAR UNDER THE VEHICLE NEAR THE PLUME, BUT NO IMPACT OCCURS.

TV-7 Views entire launch vehicle from camera site 2
Color M-II east of pad.

Comments: A BIRD CLOSE TO THE CAMERA CROSSES THE FRAME FROM RIGHT TO LEFT AT T+3 SECONDS, BUT NO CONTACT OCCURS. AT T+5 SECONDS, AN UNIDENTIFIED EVENT IS VISIBLE UNDER THE RH SRB AFT SKIRT - MAY BE UNUSUAL OUTGASSING OR BURNING OF THE INSTAFOAM, OR LOOSE THERMAL CURTAIN TAPE. EVENT HAS TERMINATED BY T+6 SECONDS. CONDENSATE ON ET AFT DOME VAPORIZES. NO ANOMALIES IN SSME PLUME.

TV-13 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: SOFT FOCUS DUE TO ATMOSPHERIC EFFECTS. RECIRCULATION PHENOMENON OCCURS AT THE EXPECTED TIME. SUNLIGHT IS MOMENTARILY REFLECTED OFF THE ORBITER HATCH WINDOW. SSME PLUME REFLECTIONS OCCUR ON THE SRB IEA'S. SRB SEPARATION IS NOMINAL AND BSM BURN SCAR ON THE ET OGIVE IS WITHIN THE DATABASE.

TV-16 View from helicopter orbiting west of pad and VAB.
Color M-II

Comments: TOO DISTANT FOR CLOSE-IN DETAIL AND NO TRACKING WAS ATTEMPTED.

TV-18 Malabar ITEC video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: TOO DISTANT FOR CLOSE-IN DETAIL AND FOCUS IS SOFT DUE TO ATMOSPHERIC EFFECTS. SRB SEPARATION APPEARS NOMINAL AND NO SLAG PARTICLES ARE OBSERVED.

ET-204 Patrick IGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: POOR IMAGE QUALITY DUE TO ATMOSPHERIC EFFECTS. RECIRCULATION PHENOMENON OCCURS AT APPROXIMATELY THE EXPECTED TIME. SRB SEPARATION IS NOMINAL AND BSM SCAR ON THE ET OGIVE APPEARS TO BE WITHIN THE DATABASE.

ET-206 Melbourne Beach ROTI video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: POOR IMAGE QUALITY DUE TO ATMOSPHERIC EFFECTS. RECIRCULATION PHENOMENON OCCURS AT APPROXIMATELY THE EXPECTED TIME. SRB SEPARATION APPEARS NOMINAL AND THE BSM SCAR ON THE ET OGIVE IS WITHIN THE DATABASE. NO VEHICLE ANOMALIES.

ET-207 UCS-10 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: SUNLIGHT REFLECTIONS OCCUR ON THE ORBITER, ET, AND SRB NOSECAPS. PLUME REFLECTION IS VISIBLE ON THE SRB IEA'S AND THE UNDERSIDE OF THE OMS POD. AERODYNAMIC SHOCK WAVE EXPANSION FORMS ON BOTH SIDES OF THE VEHICLE. AT T+61 SECONDS, A SHOWER OF PARTICLES OR PUFF OF VAPOR, BACKLIT BY THE SUN, BEGINS TO DISSIPATE NEAR THE 2058 RING. THIS EVENT APPEARS TO ORIGINATE NEAR THE ET INTERTANK AREA, POSSIBLY NEAR THE GUCP. THE SOURCE OF THIS EVENT IS MOST LIKELY ONE OF THE THREE PIECES OF ACREAGE FOAM REVEALED BY ON-ORBIT FLIGHT CREW PHOTOGRAPHY TO BE MISSING FROM THE INTERTANK -Y-Z THRUST PANEL, BUT MIGHT ALSO BE: ICE/FROST FROM GUCP, OR THE LH SRB RSS -Z ANTENNA TPS RAMP. SRB SEPARATION IS NOMINAL.

ET-208 Cocoa Beach DOAMS video. Tracks launch vehicle
Color M-II from acquisition to LOV.

Comments: SOFT FOCUS DUE TO ATMOSPHERIC EFFECTS. RECIRCULATION PHENOMENON OCCURS AT THE EXPECTED TIME. SUNLIGHT IS MOMENTARILY REFLECTED OFF ORBITER WINDOW. SRB SEPARATION IS NOMINAL.

ET-212 UCS-23 MIGOR video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: MANY BIRDS ENTER FOV BETWEEN VEHICLE AND CAMERA, BUT NO CONTACT WITH THE VEHICLE OCCURS. TYPICAL AERODYNAMIC SHOCK WAVE EXPANSION FORMS ON VEHICLE. NO SLAG OR DEBRIS PARTICLES FALL FROM SEPARATED SRB'S.

ET-213 UCS-7 MOTS video. Tracks launch vehicle from
Color M-II acquisition to LOV.

Comments: SRB SEPARATION IS NOMINAL AND NO SLAG OR DEBRIS PARTICLES FALL FROM THE BOOSTERS.

STARCAST Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Medium FOV - 9" fixed lens.

Comments: CAMERA OVERDRIVEN. ONLY PLUME VISIBLE.

STARCAST Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Narrow FOV - 60" fixed lens.

Comments: TRACKING IS INITIALLY ERRATIC, BUT IMPROVES. VEHICLE ACQUIRED JUST PRIOR TO SRB SEPARATION. OVEREXPOSURE OBSCURES MOST VEHICLE DETAIL. SRB SEPARATION APPEARS NORMAL. NO VEHICLE ANOMALIES.

STARCAST Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Wide FOV.

Comments: AIRCRAFT WINDOW REFLECTION IS VISIBLE. VEHICLE IS VERY SMALL IN FRAME AND DETAIL CANNOT BE RESOLVED.

STARCAST Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Narrow FOV.

Comments: SAME AS 60" FIXED LENS NARROW FOV ITEM ABOVE EXCEPT EXPOSURE IS BETTER. SRB SEPARATION IS NORMAL. NO DEBRIS NOTED FOLLOWING SEPARATION. VEHICLE TRACKED FOR 5 MINUTES 24 SECONDS AFTER SRB SEP. NO VEHICLE ANOMALIES.

HALO Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Super Wide FOV.

Comments: AIRCRAFT WINDOW REFLECTIONS AND DEFECTS ARE APPARENT. VEHICLE IS VERY SMALL IN FRAME AND DETAIL CANNOT BE RESOLVED. VEHICLE PASSES BETWEEN SUN AND AIRCRAFT CREATING INTENSE GLARE.

HALO Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Aft camera - Narrow FOV.

Comments: AIRCRAFT WINDOW REFLECTIONS (HONEYCOMB) AND DEFECTS ARE APPARENT. ACQUISITION OCCURS AT 4:58:04 GMT. SEVERAL FRAMES PROVIDE A CLEAR, FOCUSED VIEW OF THE VEHICLE, BUT TRACKING IS VERY ERRATIC. SUN GLARE ON WINDOW AND LENS ARE VISIBLE IN FOV. THE PLUME RECIRCULATION EFFECT AND A REFLECTION OF THE SUN OFF THE ORBITER NOSE CAN BOTH BE SEEN PRIOR TO SRB SEPARATION. TRACKING IS LOST AT THE MOMENT OF SRB SEPARATION. AFTER SEPARATION, MANY PARTICLES CAN BE SEEN COMING FROM THE AFT SKIRT AREAS OF BOTH SRBs. THESE PARTICLES ARE MOST LIKELY PIECES OF INHIBITOR, BURNING PROPELLANT, AND AFT SKIRT INSTAFOAM. TRACKING IS LOST SHORTLY AFTER SEPARATION AND WAS NOT REGAINED.

HALO Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Forward camera - Wide FOV.

Comments: CAMERA LENS AND AIRCRAFT WINDOW DEFECTS ARE VISIBLE. SUN GLARE IS SEVERE. ACQUISITION OCCURS AT 4:58:04 GMT. VEHICLE IS TOO SMALL TO RESOLVE DETAIL. SRB SEPARATION APPEARS NORMAL.

HALO Aerial tracking of launch vehicle from acquisition
B/W M-II to LOV. Aft camera - Wide FOV.

Comments: CAMERA LENS AND AIRCRAFT WINDOW DEFECTS ARE VISIBLE. STRONG SUN GLARE. ACQUISITION OCCURS AT 4:58:03 GMT. VEHICLE IS TOO SMALL TO RESOLVE DETAIL. TAPE ENDS PRIOR TO SRB SEPARATION.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Booster frustums and the LH nose cap dome were inspected for debris damage/sources at CCAFS Hangar AF on 15 March 1989 from 1230 to 1430 hours. The remainder of both SRBs were inspected on 16 March 1989 from 0830 to 1130 hours. Other than the dome of the LH nose cap, the booster nose caps were not recovered and are therefore not included in this assessment.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

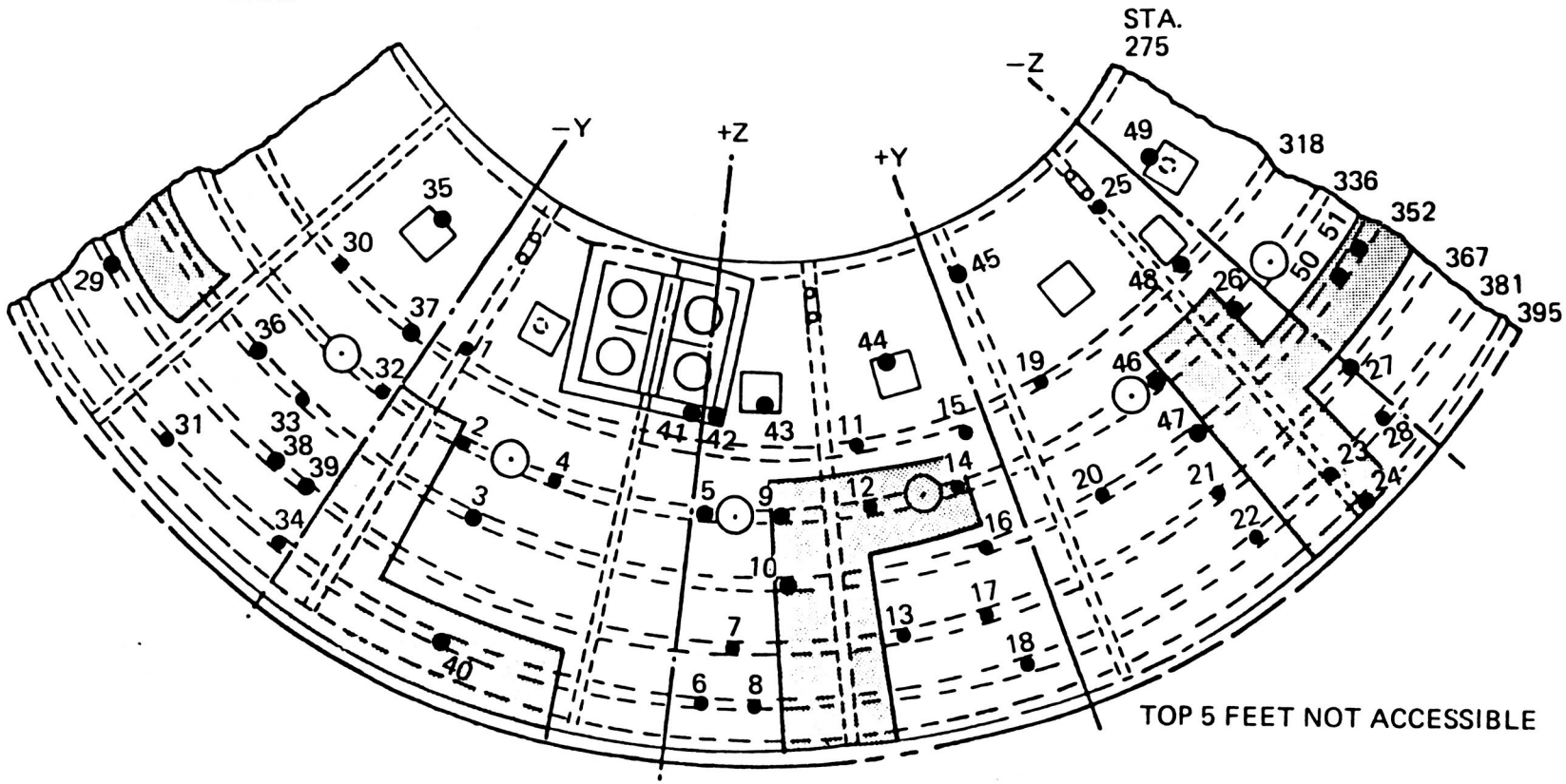
The RH frustum was not missing any MSA-2 TPS but did exhibit 51 debonds, all of which occurred over the sealant caps (Figure 7). Removal of the debonded areas revealed adhesive failure of epoxy topcoat to the sealant cap outer surface. Further inspection revealed separation of the sealant caps from the PR1422 sealant and moisture was found at the separation interface indicating possible intrusion at water impact (rapid wicking). The debond phenomenon is probably caused by incompatibility of MSA-2 solvents in contact with the santoprene rubber cap material during spray operations. No acreage debonds had occurred. There were numerous blisters in the black hypalon painted areas ranging in size from 1/4-inch to 3/4-inches in diameter. All BSM covers were intact and locked in the open position.

The RH FWD skirt exhibited missing MSA-2 TPS to substrate at two locations and the divots showed signs of heating. One of these locations had occurred in VAB processing prior to launch. Another location was missing MSA-2 with no signs of heating. The MTA-2 was gouged near the thrust post with local blistering of the hypalon paint. There were no debonds. A piece of K5NA on the RSS forward crossover was missing to substrate with evidence of heating. The hypalon paint was generally in good condition. However, "popcorning" of the paint/cork as large as 1-inch in diameter had occurred on the forward section of the systems tunnel cover (Figure 8). Phenolic plates on both RSS antennas were intact. Separation of the forward attach fitting was nominal and the cables separated cleanly. Blown grease found on the forward dome skirt seal may be indication of a leak. Five gallons of water was found inside the FWD skirt.

All factory and field joint closeouts were undamaged. Known void areas on the field joint closeout repairs remained intact. Cracks appeared in a large K5NA closeout covering DFI cables. This closeout, located at 90 degrees XB 850, had exceeded the allowable protuberance limit. A small 1" x 1/2" divot occurred on the FWD center case DFI run 100 degrees XB 938.98 (Figure 9). Trailing edge damage to DFI cork runs was attributed to debris from nozzle extension severance. Instrumentation ID epoxy-covered labels were debonded, and in many cases, missing altogether.

FIGURE 7. **RIGHT SRB FRUSTUM**

NOTE: Numerous Paint Blisters Ranging from ¼ " – ¾ " Diam.



MISSING TPS

NONE

DEBONDS

1. 3 x 2
2. 2 x 1½
3. 1½ x 1½
4. 1½ x 1½
5. 1½ x 1½
6. 2 x 1½
7. 3 x 1½
8. 2 x 2
9. 2½ x 1
10. 2 x 1
11. 3 x 1½
12. 2½ x 1½
13. 2¼ x 1½
14. 2 x 1½
15. 3 x ½
16. 1 x 1
17. 3 x 1½
18. 2¼ x 1¼
19. 3½ x 1½
20. 2 x 1¼
21. 3 x 2
22. 2½ x 1¼
23. 1 x 1
24. 1 x 1
25. 2½ x 2
26. 2¼ x 1¼
27. 1½ x 1½
28. 2½ x 1½
29. 3 x 2
30. 2½ x 1½
31. 5 x 1½
32. 3 x 2½
33. 2½ x 2½
34. 1½ x 1½

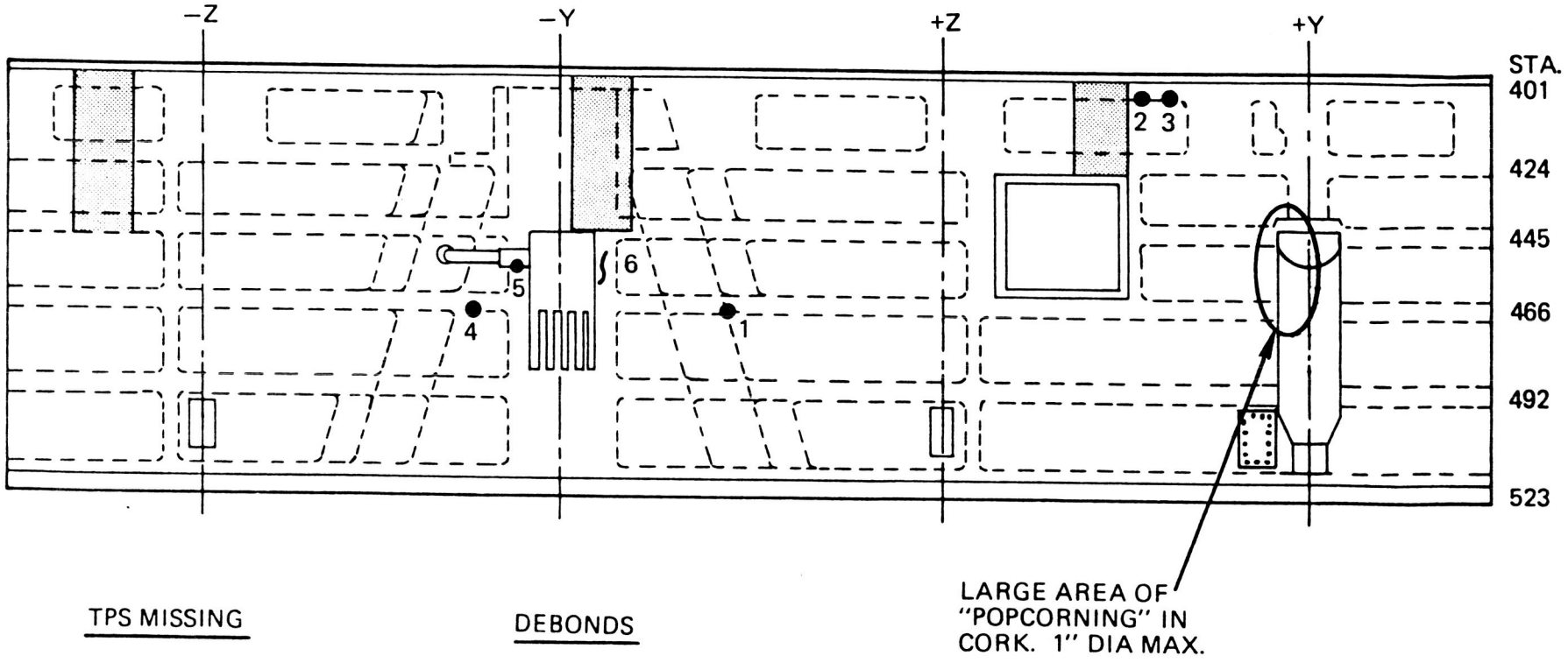
NOTE

NO ACREAGE DEBONDS

DIMENSIONS FOR DEBONDS # 35 – 51 WERE UNAVAILABLE BUT SIMILAR TO # 1 – 34.

EGG/V-326

FIGURE 8. **RIGHT SRB FWD SKIRT**



TPS MISSING

1. ½" DIA – Divot Occurred Prior to Launch
2. ¼" x ¼" MSA–2
3. 1" x ½" MSA–2 MISSING TO SUBSTRATE
4. ½" x ¼" HYPALON BLISTER – MTA 2 MISSING
5. ½" x 1 ½" K5NA MISSING TO SUBSTRATE
6. GOUGE IN MTA–2 WITH ADJACENT BLISTERING

DEBONDS

NONE

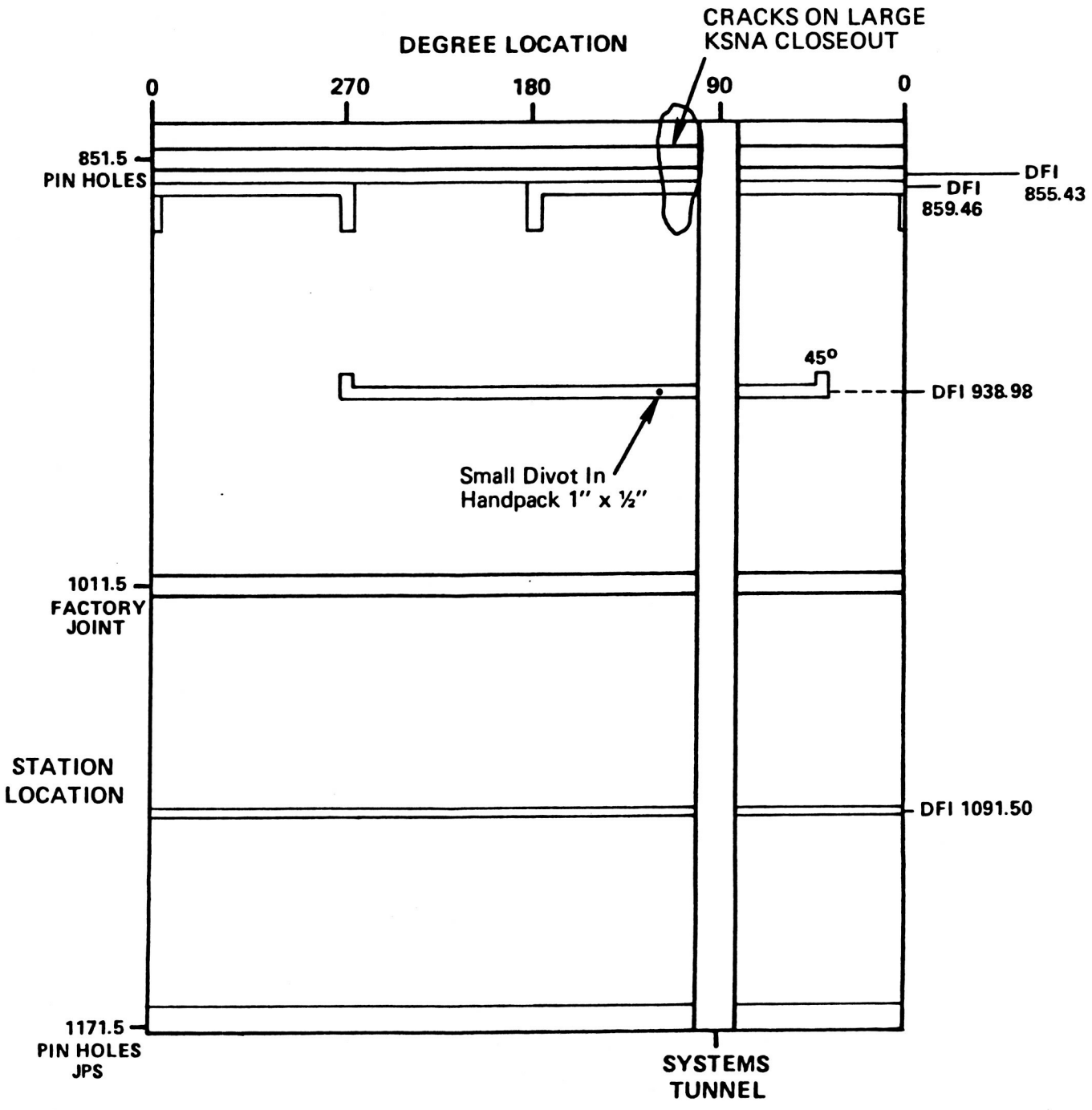


FIGURE 9. **RIGHT FORWARD CENTER CASE SEGMENT**

All three stiffener rings showed signs of water impact damage with cracked webs and K5NA. Separation of the aft ET/SRB struts was nominal. The K5NA closeouts on the IEA covers, which had been waived due to shortened cure time on the pad, were intact.

Numerous divots had occurred above the aft skirt phenolic kick ring. K5NA was missing from around all four BSM nozzles. The TPS over the aft skirt acreage was generally in good condition. As a result of early nozzle extension severance, the aft booster was darker (more sooted) than usual and considerable heating effects were evident under the aft skirt. Most of the blue rain shield material and velcro fasteners were missing from the aft ring. Much of the instafoam used to protect the TVC from water impact damage was burnt or had been lost prior to splashdown. The loss of foam was especially acute at the 90-180-270 location and around the holddown post feet. The trust vector control system was a total loss.

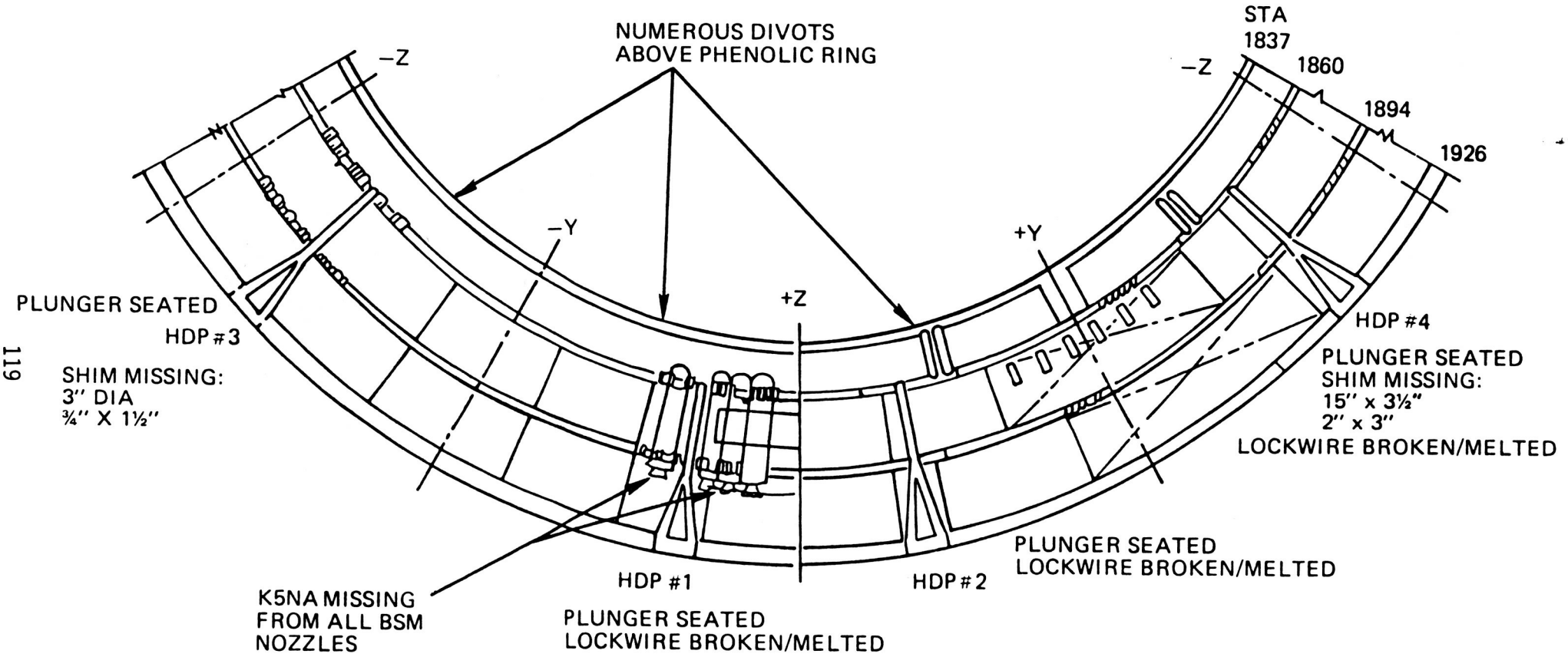
All four of the aft skirt debris containers with attach bolts were intact, though the lockwire had melted or broken on posts #1 and #2. All four of the debris plungers were seated properly. Two pieces of Epon shim (3-inch dia and 1-1/2"x3/4") were missing from post #3 as were two pieces (15"x3-1/2" and 3"x2") from post #4 (Figure 10).

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was not missing any MSA-2 TPS but did exhibit 31 debonds, 29 of which had occurred over the sealant caps (Figure 11). Removal of the debonded areas revealed adhesive failure of the epoxy topcoat to the sealant cap outer surface. Further inspection revealed separation of the sealant cap from the PR1422 sealant and moisture was found at the separation interface indicating possible intrusion at water impact (rapid wicking). The debond phenomenon was probably caused by incompatibility of the MSA-2 solvents in contact with the santoprene rubber cap material during spray operations. Two acreage debonds, with cracks, of MSA-2 to the topcoated aluminum structure had occurred. There were numerous blisters in the hypalon paint averaging 1/8-inch to 1/2-inch in the white areas and 1/8-inch to 5-inches in the black visibility stripes. All BSM covers were intact and locked in the open position.

The LH FWD skirt was missing MSA-2 TPS to substrate at two locations and the divots showed signs of heating. Three other locations exhibited missing MSA-2, but the substrate was not exposed. MTA-2 TPS was missing from one location. There were no debonds (Figure 12). The -Z RSS antenna forward ramp lost a 6-1/2"x5-1/8" piece of SLA 220 TPS with clear signs of adhesive failure on the substrate (75% of the total missing material) and an additional 25% of the SLA 220 failed cohesively. There was slight sooting of the remaining material. The phenolic

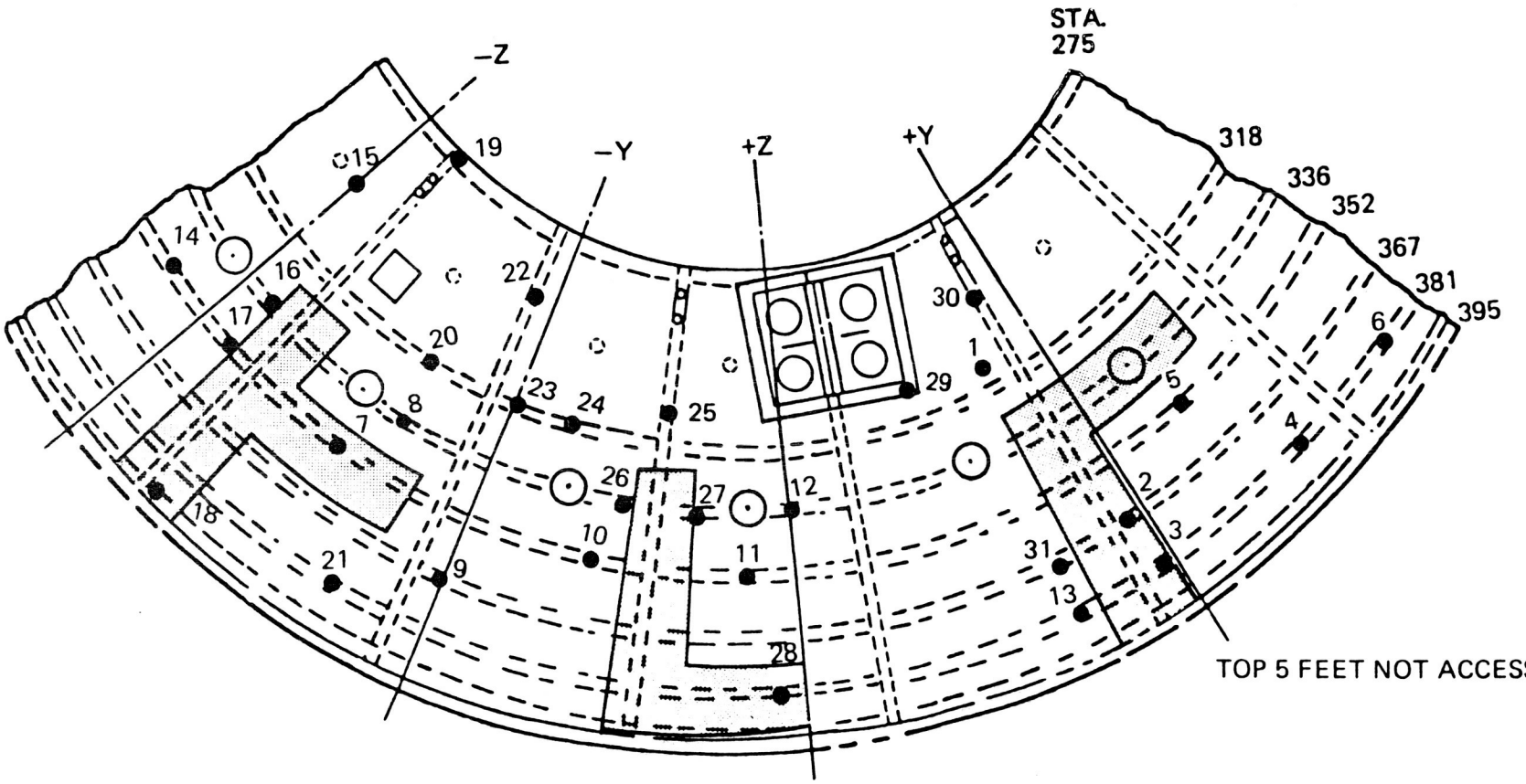
FIGURE 10. **RIGHT SRB AFT SKIRT EXTERIOR TPS**



EGG/V 326C

FIGURE 11. LEFT SRB FRUSTUM

NOTE: Numerous Paint Blisters On
White Paint @ = 1/8" to ½" AVG
Black Paint = 1/8" to 5"



MISSING TPS

NONE

DEBONDS

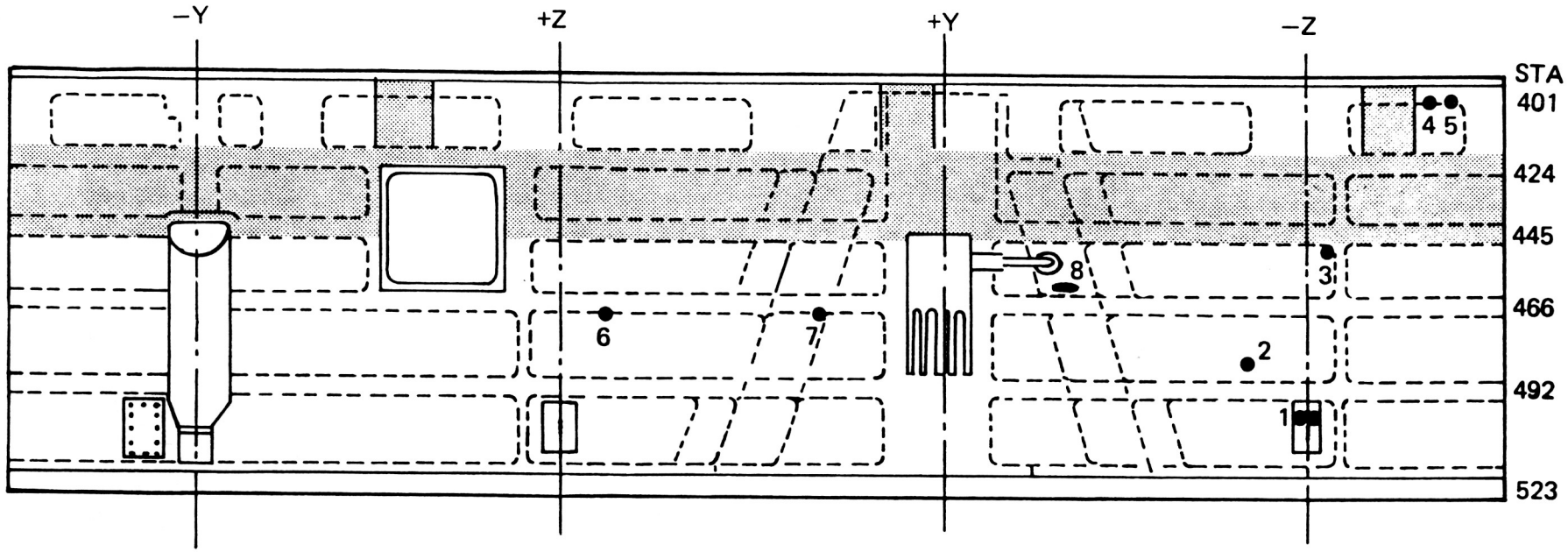
1. 2 x 2 (ACREAGE DEBOND)
2. 2 x 2
3. 2 x 2
4. 1½ x 1½
5. 3 x 1½
6. 2 x 1½
7. 3 x 1½
8. 3 x 1½
9. 2½ x 1½
10. 3 x 2
11. 2 x 1
12. 2 x 1½
13. 2 x 2

NOTE

DIMENSIONS FOR DEBONDS # 14 – 31 WERE UNAVAILABLE BUT SIMILAR IN SIZE TO # 1 – 13.

EGG/V-326E

FIGURE 12. **LEFT SRB FWD SKIRT**



TPS MISSING	DEBONDS
1. 8" x 5" SLA	NONE
2. ¼" x ¼" MSA–2	
3. 3/8" x 1/2" MSA–2 TO SUBSTRATE	
4. ½" x ¼" MSA–2	
5. 5/8" x ¼" MSA–2	
6. ½" x 1" MSA–2 TO SUBSTRATE	
7. ½" x 1" MTA–2	
8. 2 DIVOTS ¼" DIA BLISTERS	

plates on both RSS antennas were intact. Separation of the forward attach fitting was nominal. Five gallons of water was found inside the FWD skirt.

All field joint closeouts were undamaged and known void areas in field joint closeout repairs were still intact. Two factory joints, one on the FWD center case XB 1011.5 (180 degrees) and the second on the aft center case XB 1331.5 (90-270 degrees), experienced a debonding of the vulcanized protective cover (Figures 13 and 14). Trailing edge damage to the DFI cork runs was attributed to debris from the nozzle extension severance. Instrumentation epoxy-covered ID labels had debonded or were missing. The pressure transducer ramps exhibited multiple debonds, but no TPS was missing.

Stiffener rings, instafoam, and the IEA structure sustained only minor water impact damage. Separation of the aft ET/SRB struts was nominal. The K5NA closeouts on the IEA cover, which had been waived due to shortened cure time on the pad, were intact.

Numerous divots had occurred above the aft skirt phenolic kick ring. K5NA was missing from around all four BSM nozzles. The TPS over the aft skirt acreage was generally in good condition. As a result of the early nozzle extension severance, the aft skirt was darker (more sooted) than usual and considerable heating effects were evident under the aft skirt. Most of the blue rain shield material and velcro fasteners were missing from the aft ring. Much of the instafoam used to protect the TVC from water impact damage was burnt or had been missing prior to splashdown. The thrust vector control system was a total loss.

All four of the aft skirt debris containers with attach bolts were intact, though the lockwire had melted or broken on posts #5, 6, and 7 (Figure 15). All four of the debris plungers were seated properly. Two pieces of Epon shim (12"x2" and 6"x3") were missing from post #8. The substrate had been blackened.

7.3 RECOVERED SRB DISASSEMBLY FINDINGS

The RH SRM igniter sustained a putty blowhole at approximately 300 degrees, an expected condition according to MTI. The LH SRM igniter had no blowholes, a first since the return to flight.

One of the LH factory joints that experienced a debonded weather seal allowed sea water to enter the joint. This is a factory installed vulcanized bond. Previous experience with this design resulted in a change early in the program to eliminate the seal and provide a cork-protected pin retainer band with heavy grease coverage.

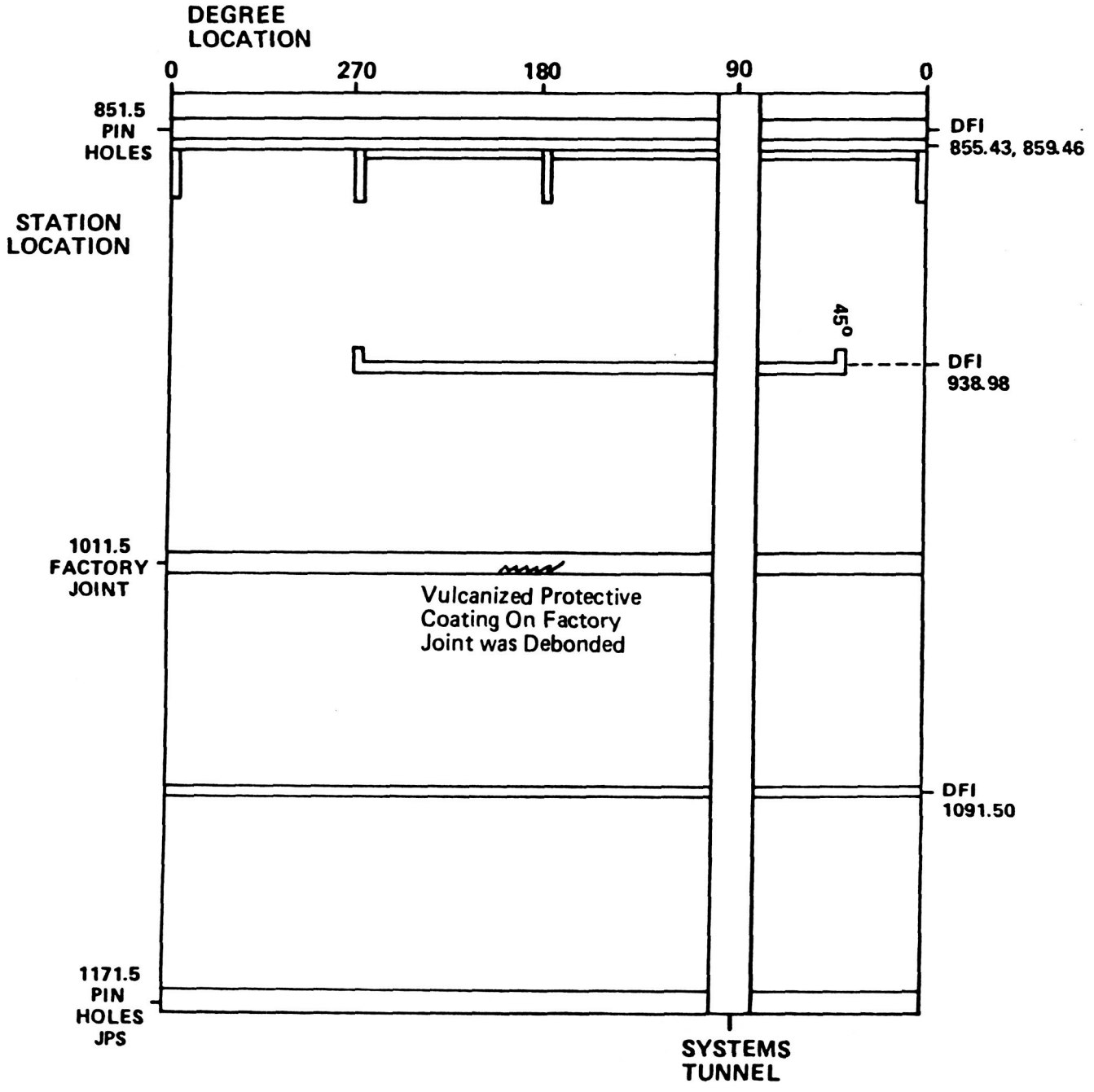


FIGURE 13. **LEFT FORWARD CENTER CASE SEGMENT**

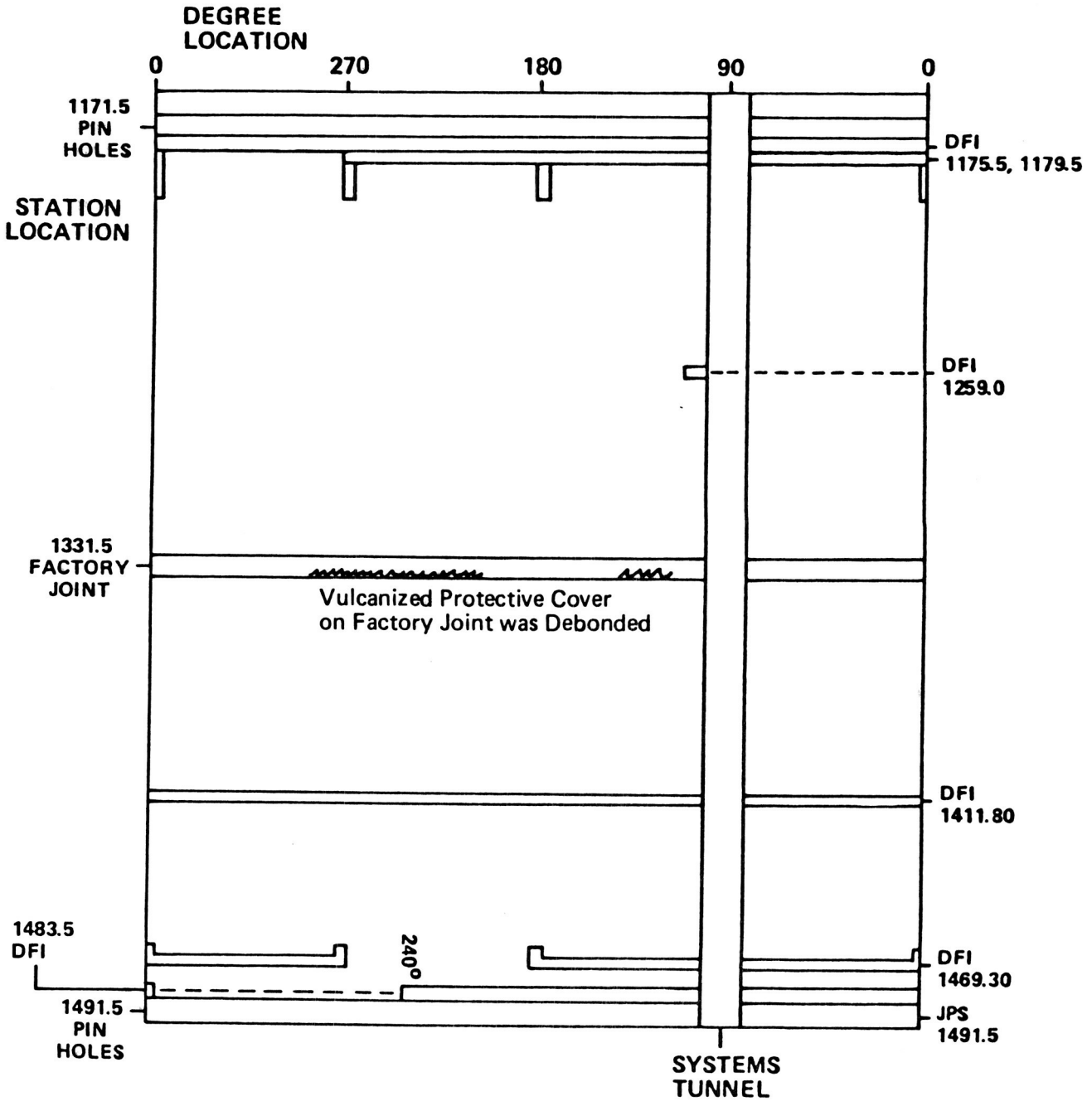
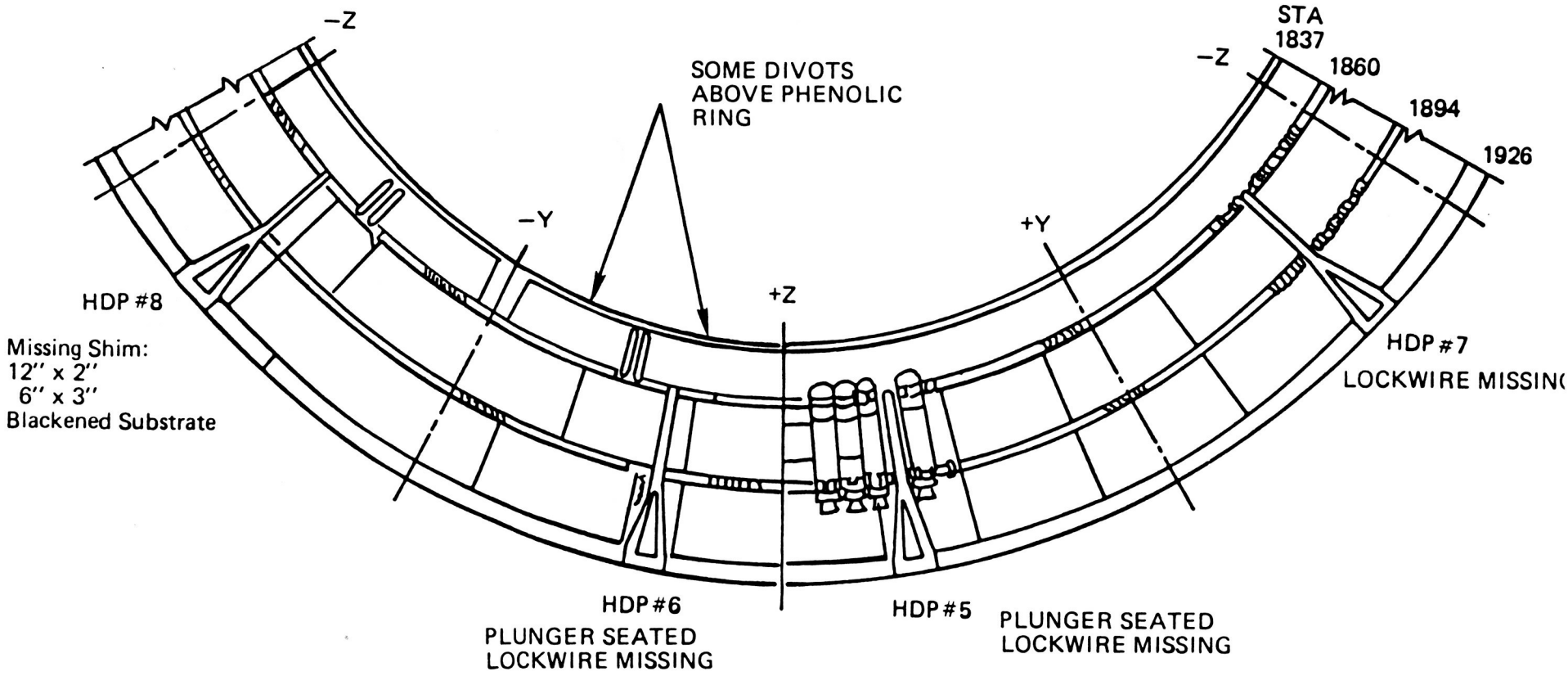


FIGURE 14. LEFT AFT CENTER CASE SEGMENT

FIGURE 15. **LEFT SRB AFT SKIRT EXTERIOR TPS**



Demating the segments resulted in similar findings from previous SRM flows. Distribution of joint fretting (cold welding) was typical, but exhibited somewhat greater dimensions at some locations. Radial inhibitor tears occurred on the forward joints and signs of the late post-separation sooting of the J-seal OD as seen on STS-26R. Several sections of the primary O-ring from the LH nozzle exit cone field joint severance area were found inside the LH SRM.

Nozzle extensions were severed at apogee for mission STS-29R instead of a time after parachute deployment and just before water impact. This change was intended to eliminate damage to the parachutes by nozzle extension fragments. However, the change caused greater heating under the aft skirt and was most probably the cause of the TVC pressure loss and damage. The foam in the aft skirt, which provides shock attenuation at water impact, was lost or damaged to the point that the K5NA TPS protection on the structure was exposed to heat. Structural damage in the form of a 3-inch long crack in the center ring frame of the left aft skirt also occurred from splashdown loads as a result of the missing instafoam.

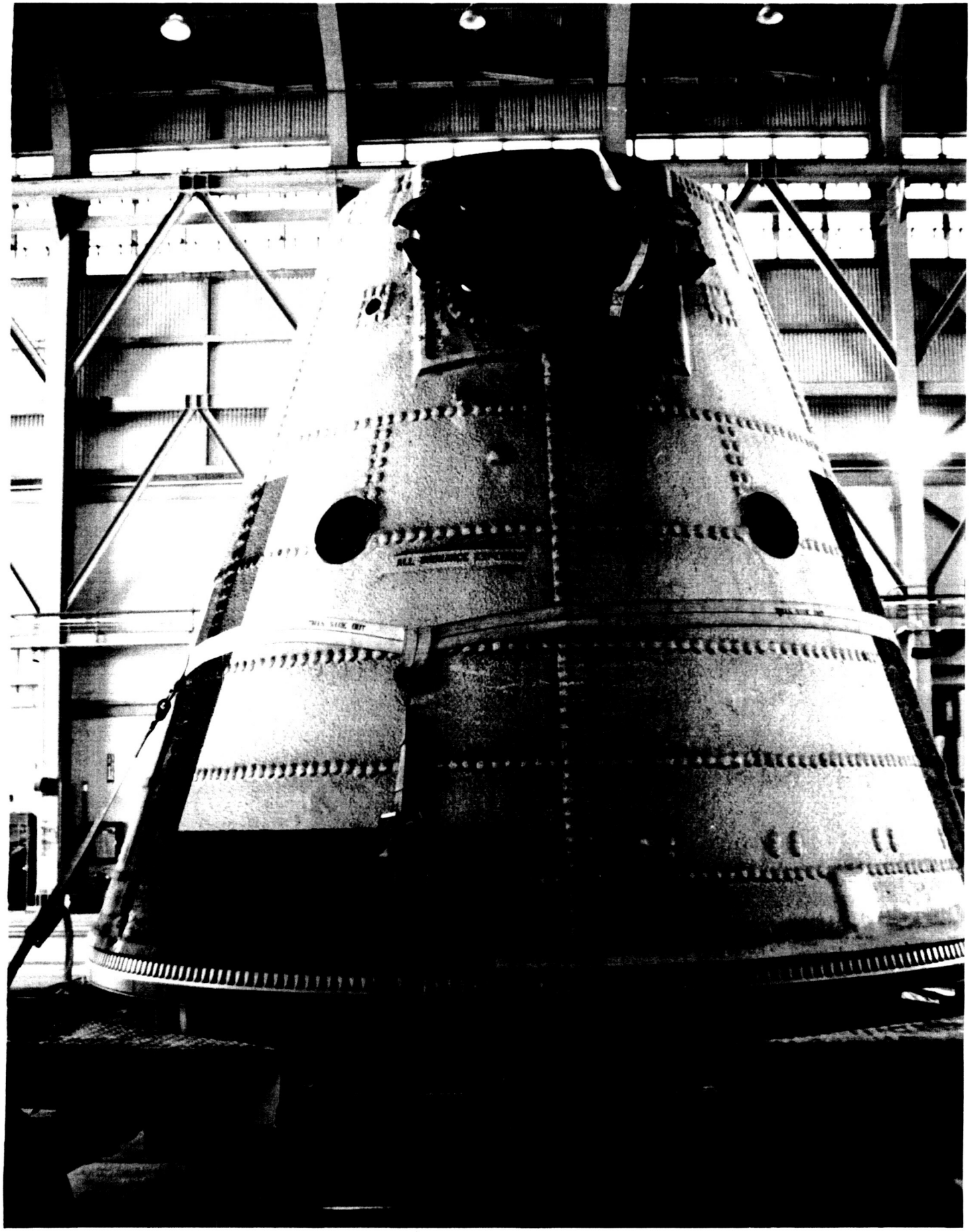
The nozzle flange joint on the LH SRB was severely damaged at water impact with sheared fasteners and stripped helicoils. The gap between the flanges allowed the O-rings to be cut and sections lost. Examination of the nozzle joint backfill material showed a good installation and no evidence of hot gas paths to the primary O-ring.

All debris container plunger assemblies were seated properly at the time of SRB recovery. However, reconstruction of the pieces in the HDP #8 debris container revealed some frangible nut fragments and most of one NSI cartridge were missing. High speed launch photography does show two fragments dropping from the aft skirt stud hole as the vehicle begins to ascend. One frangible nut fragment and one piece of NSI cartridge were found in the MLP HDP #8 sand box. In addition, posts #2, 4, and 7 also lost some frangible nut fragments.

Disassembly of the ETA ring closeouts showed overheating, melting, and breakage to the back shell of the primary joint heater connector. Pre-launch ground circuitry data had indicated a failure with the RH SRB aft field joint heater. The connector was sent to the Malfunction Analysis Branch for failure analysis (Ref laboratory report MAB-071-89).

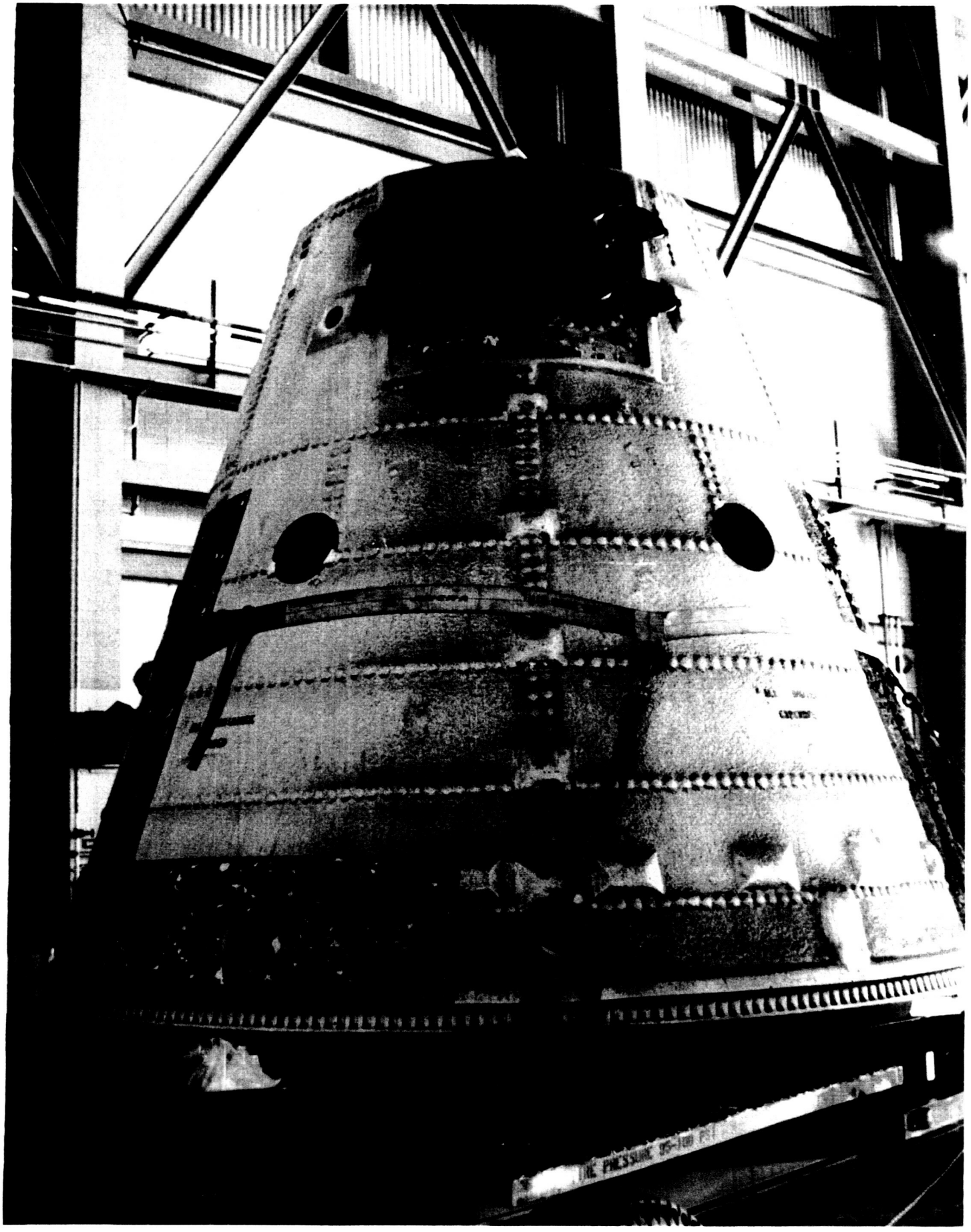
Observed SRB Post Launch Anomalies are listed in section 10.0.

ALTHOUGH NOT USUALLY RECOVERED, THIS LH SRB NOSE CAP DOME EXHIBITS NO ABLATOR ADHESION PLOBLEMS



POST FLIGHT CONDITION OF RH SRB FRUSTUM TPS/HYPALON TOPCOAT

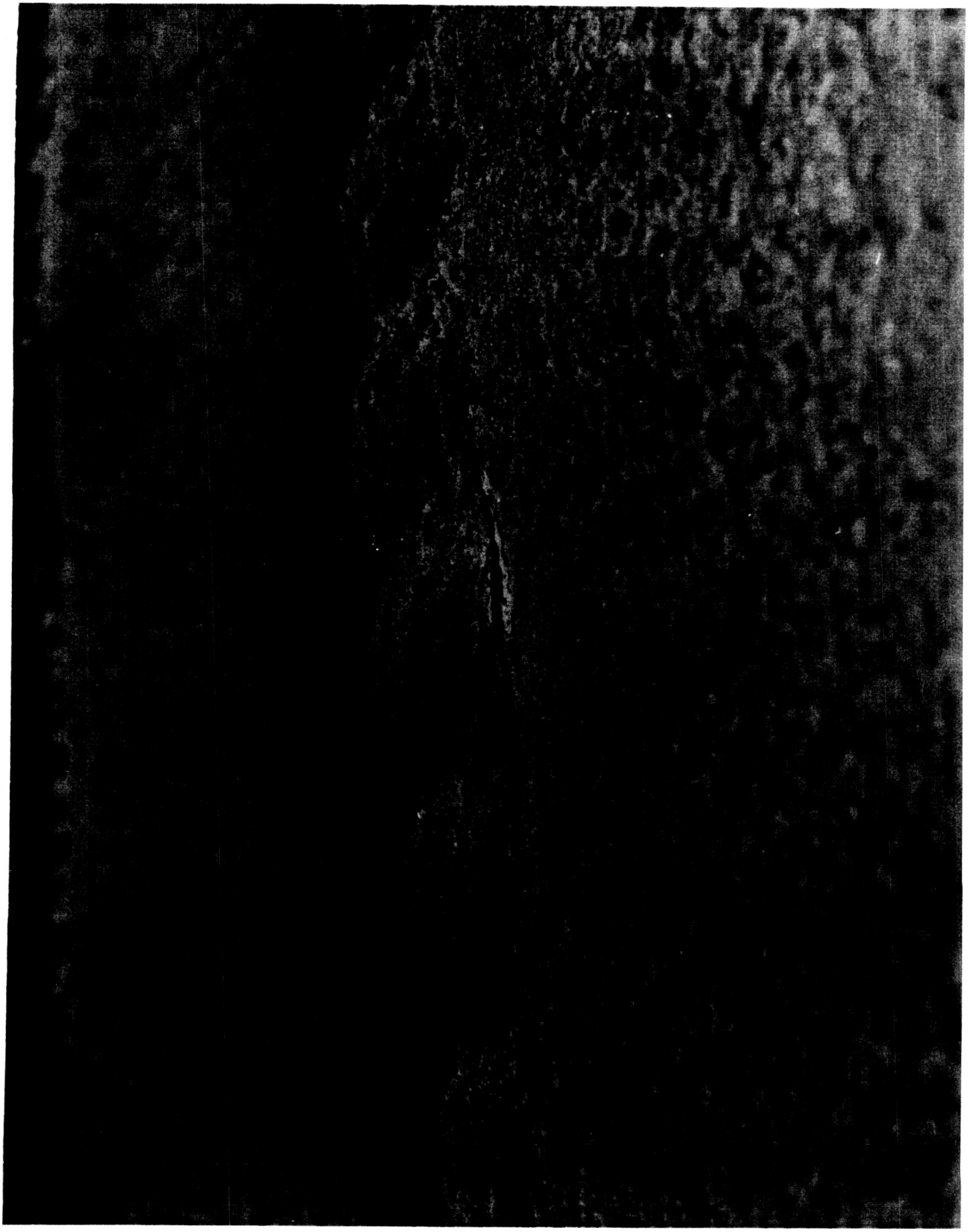
ORIGINAL PAGE
COLOR PHOTOGRAPH



POST FLIGHT CONDITION OF LH SRB FRUSTUM TPS/HYPALON PAINT
SEVERE BLISTERING OCCURRED IN BLACK VISIBILITY STRIPE

FRUSTUM MSA-2 DEBOND DUE TO ADHESIVE FAILURE OF THE EPOXY TOPCOAT TO THE SEALANT CAP OUTER SURFACE

129.1

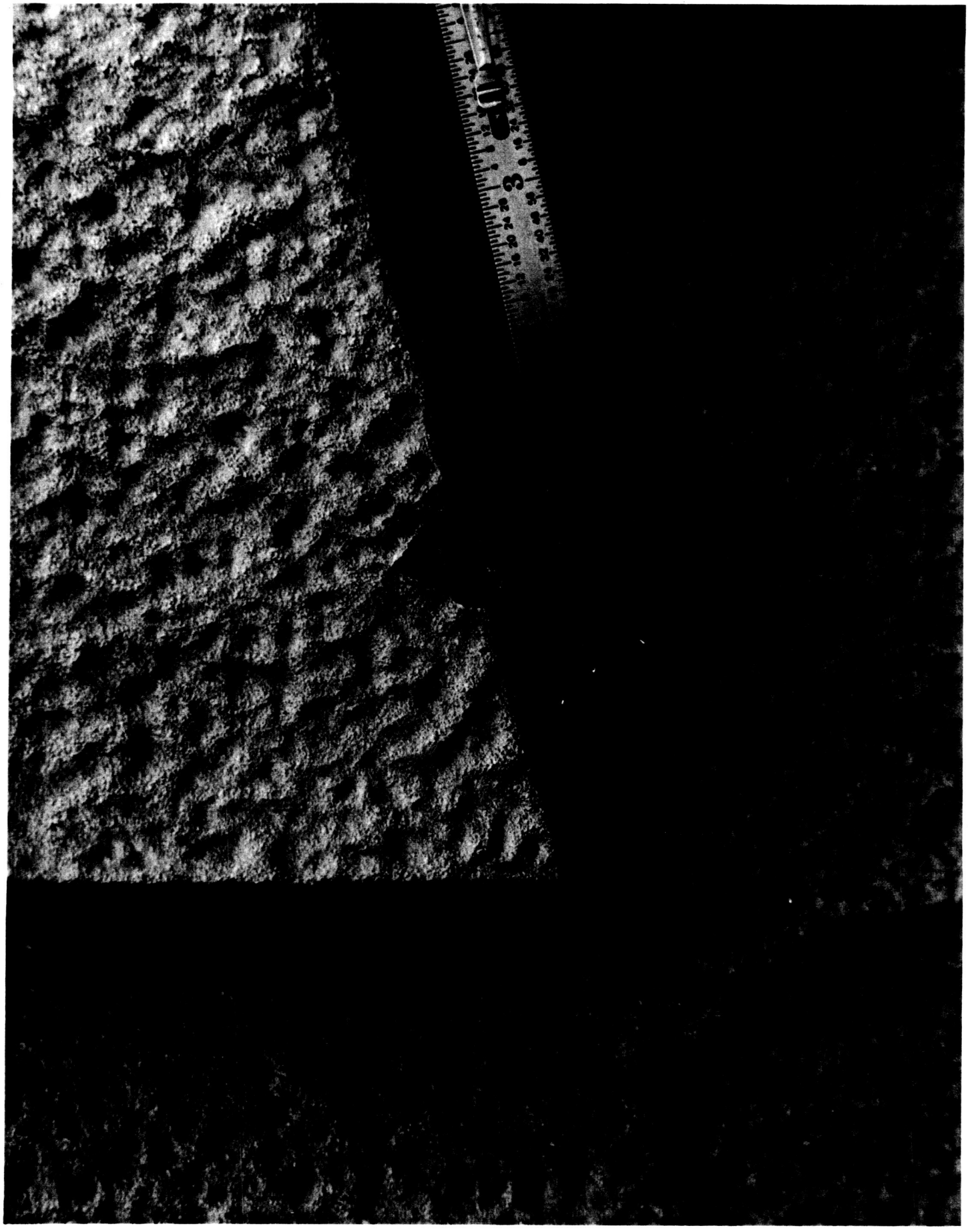


FRUSTUM DEBOND IS PROBABLY CAUSED BY INCOMPATABILITY OF MSA-2 SOLVENTS IN CONTANT WITH SANTOPRENE RUBBER SEALANT CAP MATERIAL

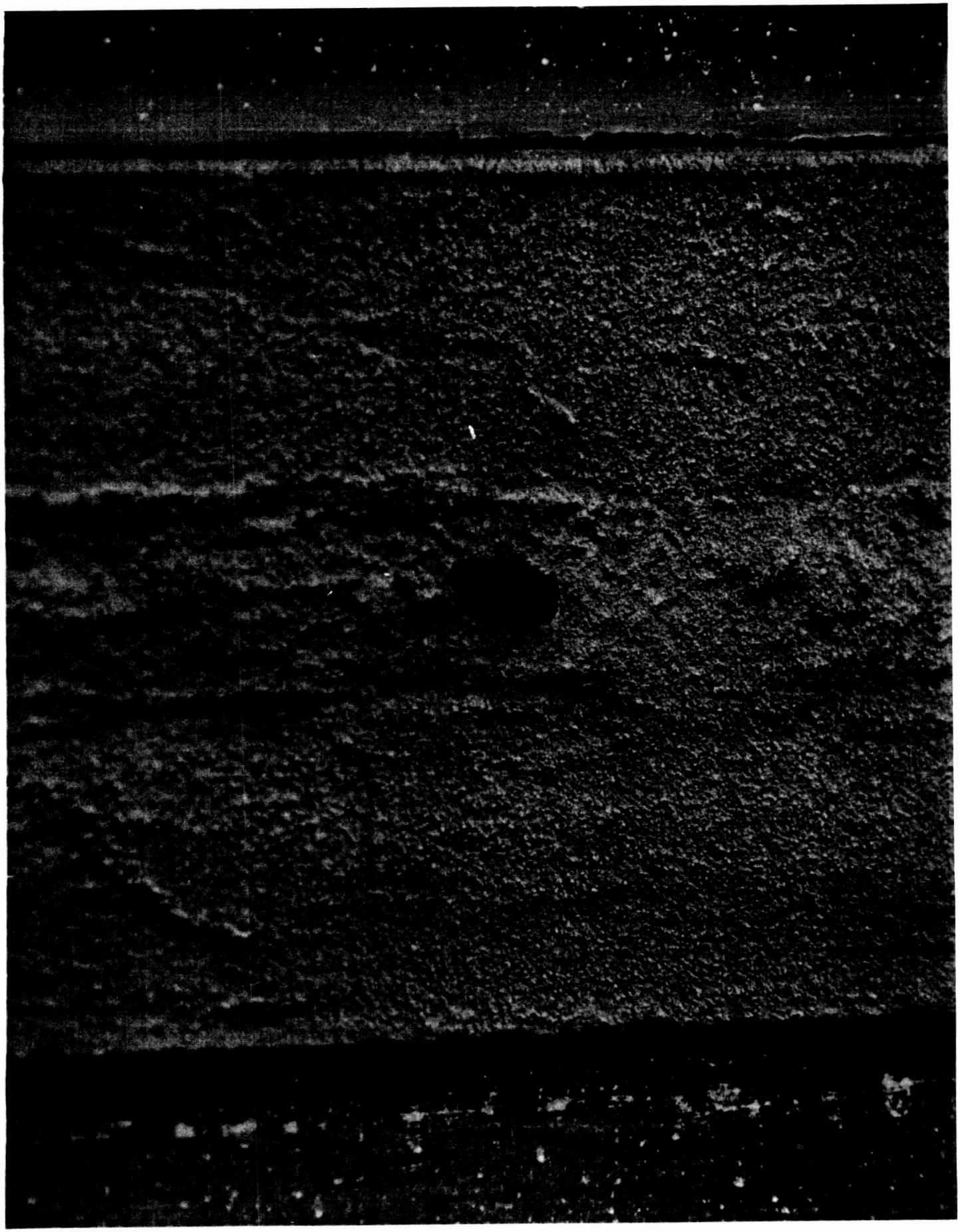
129.2

BLISTERS IN THE BLACK HYPALON TOPCOAT RANGED IN SIZE FROM 1/8-INCH TO 5 INCHES IN DIAMETER

BLISTERING OF THE PAINT/CORK AS LARGE AS 1-INCH IN DIAMETER OCCURRED ON THE RH SRB SYSTEMS TUNNEL COVER

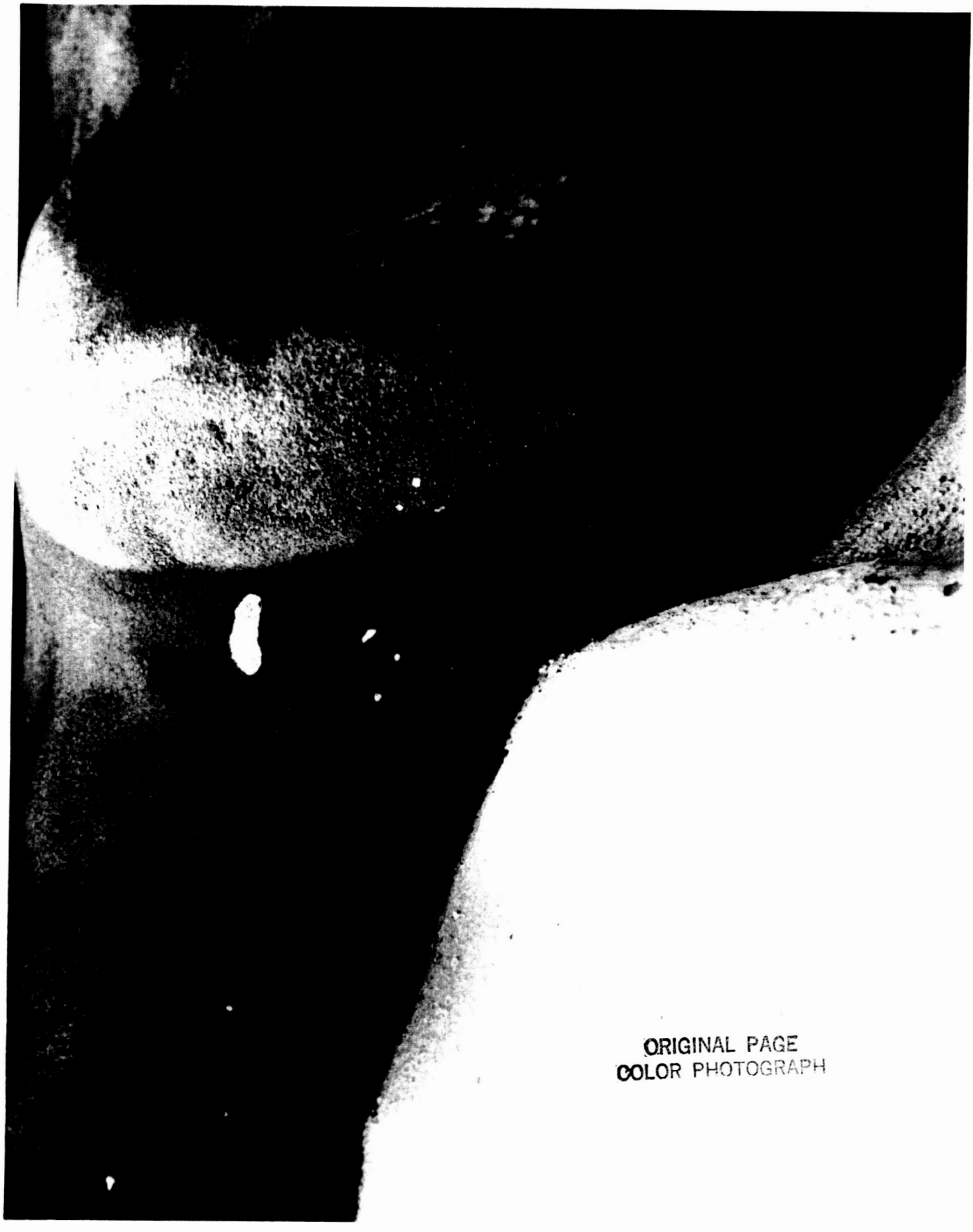


DIVOT TO SUBSTRATE ON SRB FORWARD SKIRT

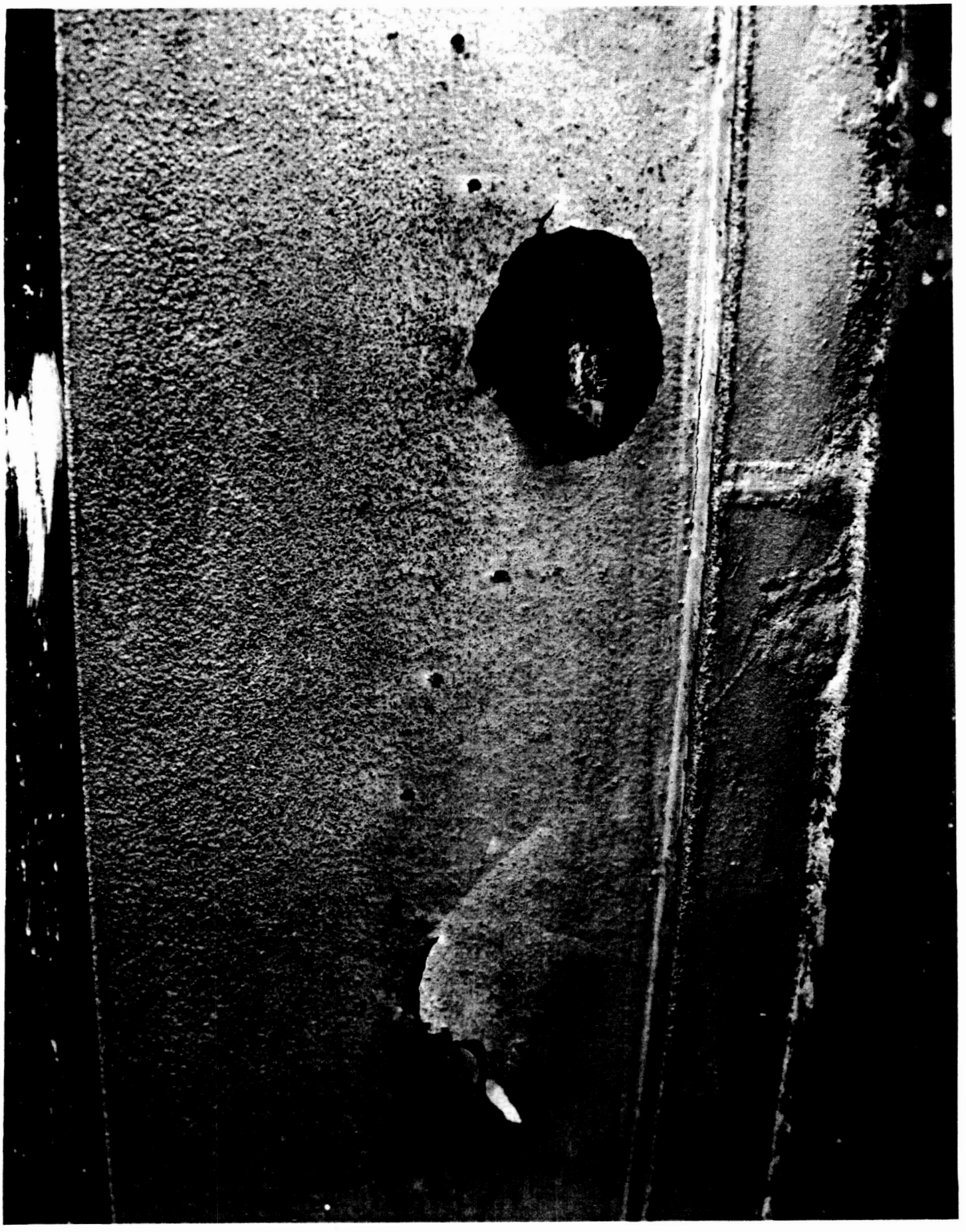


DIVOT TO SUBSTRATE SHOWS SIGNS OF HEATING ON FWD SKIRT

LARGE K5NA CABLE CLOSEOUT ON RH FWD SEGMENT EXCEEDS ALLOWABLE PROTUBERENCE LIMIT. NOTE MISSING GEI MSID TAG.



CRACKS IN LARGE K5NA CABLE CLOSEOUT ON RH FWD SEGMENT
K5NA BUILD-UP HAS EXCEEDED THE ALLOWABLE PROTUBERENCE LIMIT
134.1



LOSS OF JOINT PROTECTION SYSTEM CORK MATERIAL
IN SPITE OF DRILLED VENT HOLES

K5NA CLOSEOUTS HAD BEEN WAIVED DUE TO SHORTENED
CURE TIME ON THE PAD PRIOR TO LAUNCH

MISSING/CHARRED AFT SKIRT INSTAFOAM

K5NA IS MISSING FROM BSM NOZZLES

ORIGINAL PAGE
COLOR PHOTOGRAPH

EPON SHIM MATERIAL HAS BEEN LOST PRIOR TO WATER IMPACT

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A detailed Post Landing Inspection of OV-103 was conducted March 18-19, 1989, at Ames-Dryden (EAFB) on the concrete Runway 22 and in the Mate/Demate Device (MDD) to identify debris impacts, damage caused, and if possible, debris sources. The Orbiter sustained a total of 132 hits, of which 23 had at least one major dimension of one inch or greater.

The Orbiter lower surface had a total of 100 hits, with 18 greater than 1 inch. The upper surface sustained a total of 32 hits, with 5 greater than 1 inch. Based on these numbers, this flight is considered average when compared to statistics from 21 previous missions of similar configuration (excluding missions STS-24, 25, 26, 26R, and 27R which had damage from known debris sources). The total number of hits on the lower surface is slightly higher than normal. However, based on the severity of damage as indicated by surface area and depth, this flight is considered to be better than average. Figures 16-19 summarize the debris damage assessment for STS-29R.

The paved runway was inspected and cleaned the day prior to landing, and was clean at the time of landing.

The post landing walkdown of Runway 22 was performed at approximately L+1 hour. A piece of the outboard-forward corner tile from the RH landing gear door was found near the runway approach threshold, near a point where the landing gear door was opened. The tile corner was a 3-1/2" x 2-3/4" piece. Two pieces of AMES Gap Filler from the nose landing gear door were found along the orbiter track. Two 10" long pieces of wire, one with a connector attached, were also found. These wires were from the right main landing gear wheel pressure strain gage system. Three pieces of wire bundle tie wrap material and one 5/8" long flat head Phillips screw were also found.

Helium purge was leaking from the LH2 umbilical 17-inch QD. There was no signs of damage to the cryogenic seals that would account for the dense vapors emanating from the umbilical prior to liftoff. The LO2 umbilical 17-inch disconnect Creavey seal was flattened along a 1/2-inch length. Both umbilicals exhibited excessive foam in the flow leakcheck port closeouts, which is done after ET/ORB mate. Small particles of SOFI were embedded in the umbilical springs.

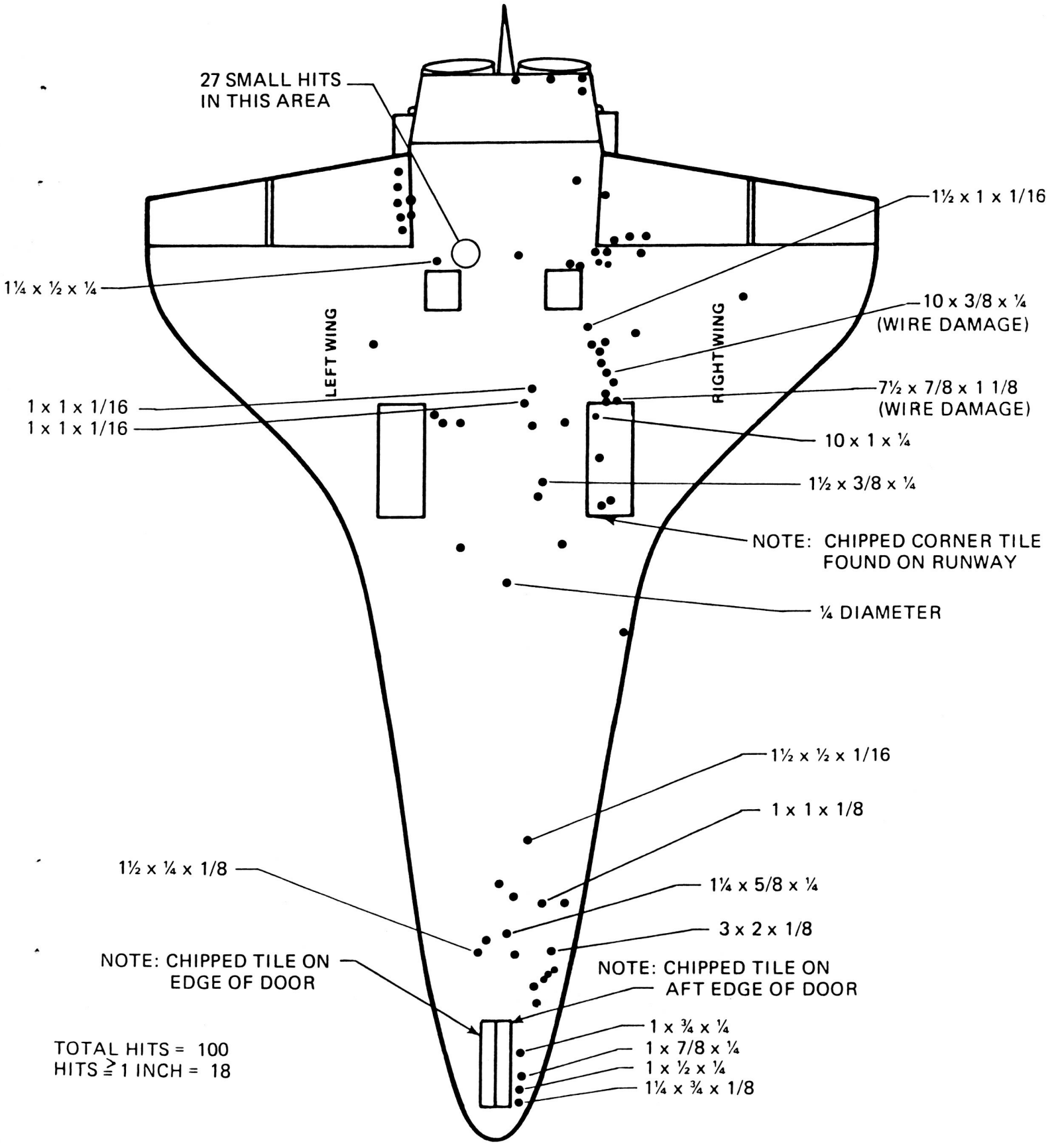
A GSE bolt was found where the baggie attaches to the structure on the ET/ORB LO2 umbilical. It was located on the inboard side of the umbilical, at approximately the 7 o'clock position (12 o'clock being forward). This bolt was 1" long with an allen head and coarse threads.

The debris plunger in the RH (LOX) EO-2 separation fitting debris container failed to seat properly in the 2-1/2 inch hole at ET/ORB separation. The plunger was jammed by two large pyro

Date: 3–19–89

FIGURE 16

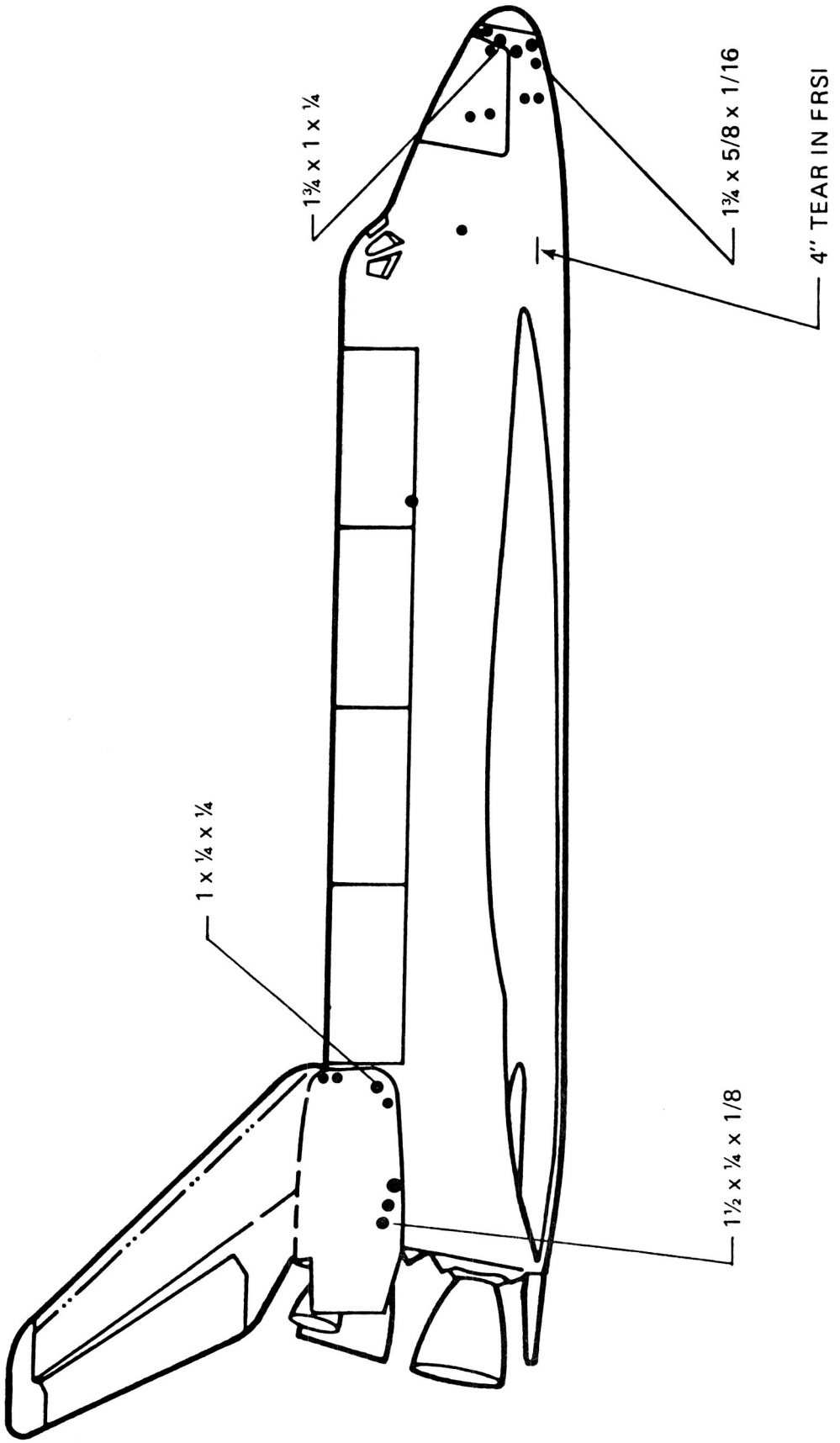
DEBRIS DAMAGE LOCATIONS



EGG V-0838

FIGURE 17

DEBRIS DAMAGE LOCATIONS

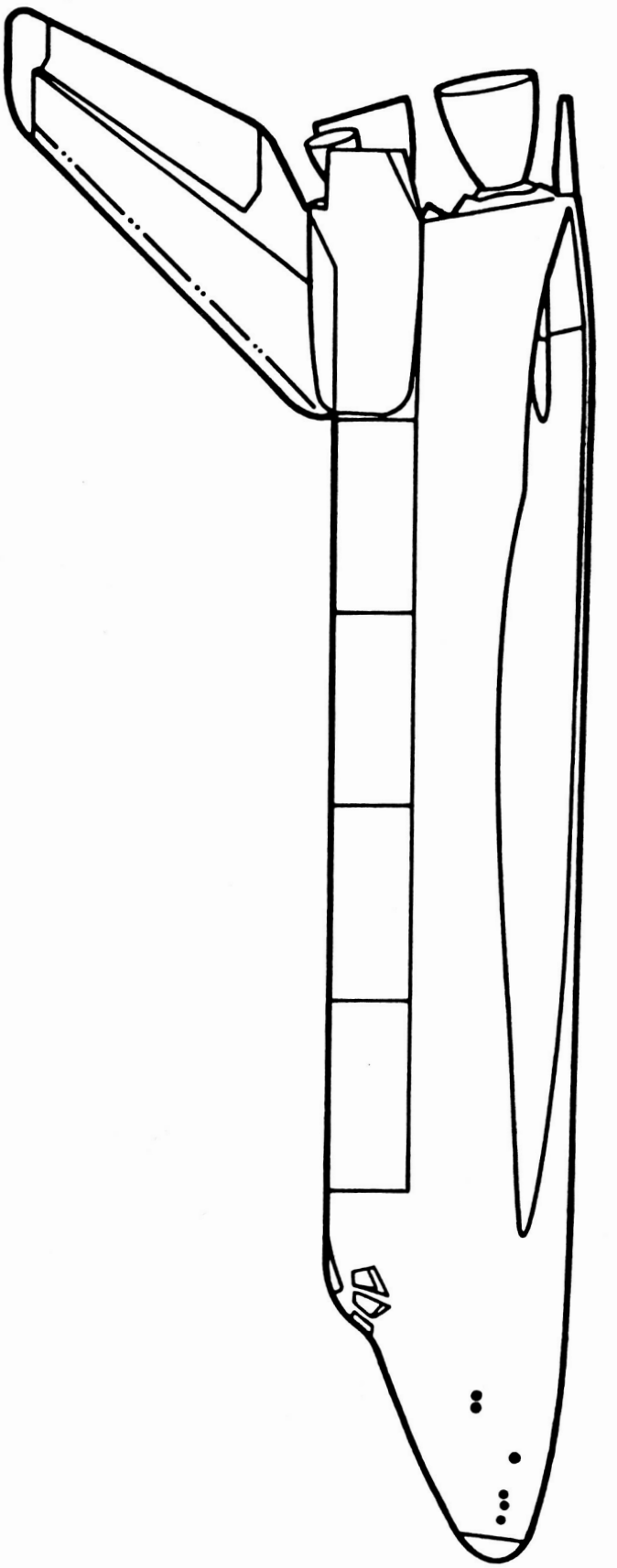


EGG/V-088A

Date: 3–19–89

FIGURE 18

DEBRIS DAMAGE LOCATIONS

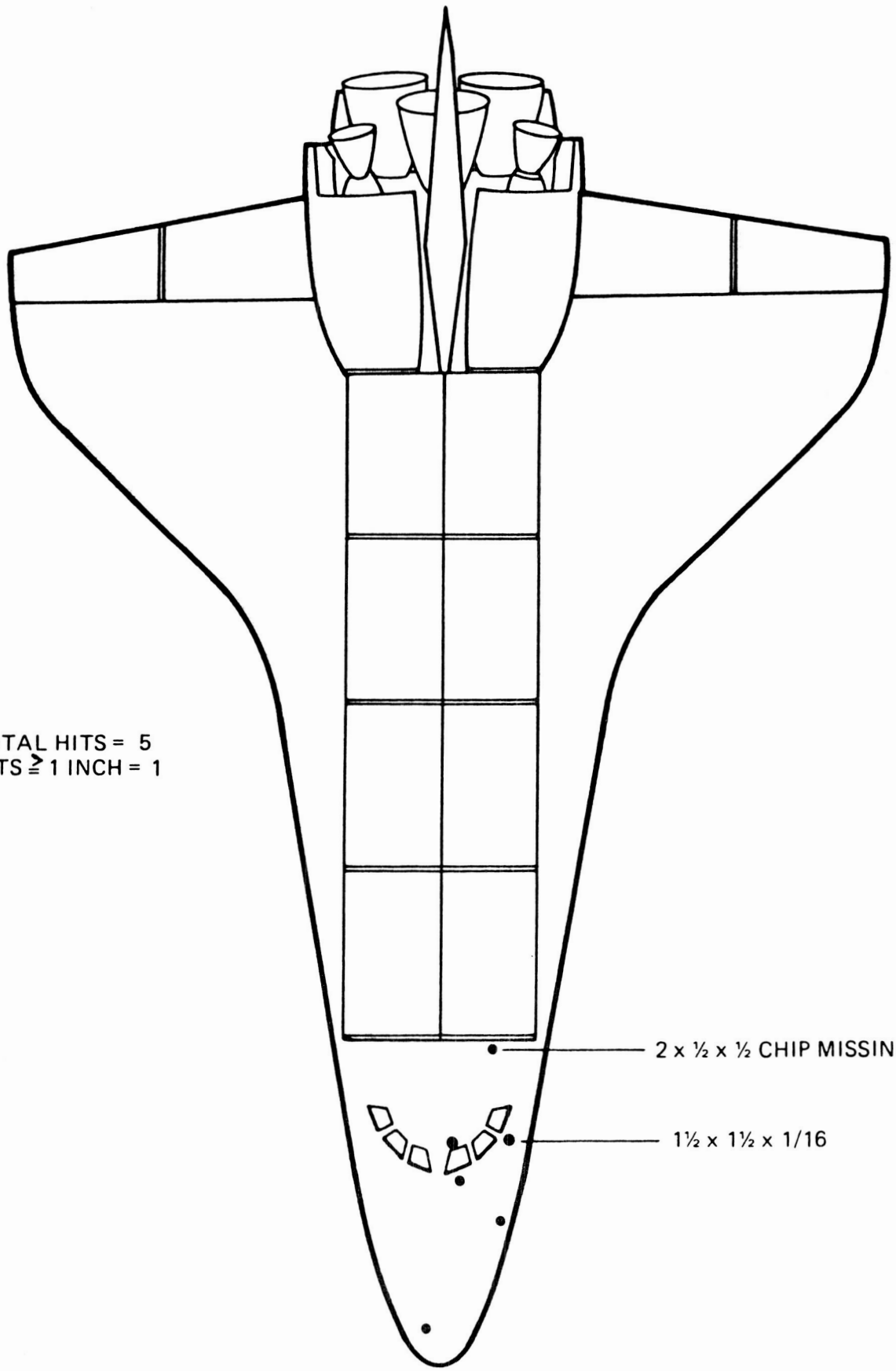


TOTAL HITS = 6
HITS ≥ 1 INCH = 0

EGG-V-088

FIGURE 19

DEBRIS DAMAGE LOCATIONS



nut fragments, which prevented the plunger from stroking and left a spring load of approximately 300-400 lbs. on the debris container lid. The plunger was modified after 51-L because of previous failures. It is listed as a Criticality I item due to the possibility of loose debris exiting the debris container into the ET door hinge/latching mechanism and causing the ET doors to fail. Two of the three LO2 umbilical separation bolt debris plungers also did not have total closure.

Although the lower surface hits were divided approximately equally between the left and right sides, 16 out of 18 hits 1-inch or greater were on the right side. A concentration of 27 small hits were located aft of the LH2 umbilical. Similar patterns have been observed on previous flights and have been attributed to umbilical ice particles released at ET separation. Several hits occurred on both sides of the fuselage immediately aft of the orbiter nose cap. The outboard wing areas and body flap sustained minimal damage (total of 9 hits, none greater than 1-inch). Two long, deep gouges (8" x 1" x 1-1/8" and 10" x 3/8" x 1/4") involving five tiles on the lower right surface just aft of the right main landing gear door were determined to be a result of impact from the wheel pressure strain gage connector and wire found on the runway.

A tile on the upper window frame of window #3 had a 1-1/2" x 1-1/2" x 1/16" hit.

Foil insulation on SSME #3 had separated and become lodged against the +Y GOX overboard vent line between hat band 7 and 8. The beta blankets on SSME #1 and #3 were badly frayed. Impacts to the base heat shield numbered less than the usual amount. Two gap fillers protruded from the base heat shield between SSME #2 and #3.

Laboratory analyses will be performed on selected tiles which have been identified to contain suspected debris inclusions.

White streaks were present on the wing leading edge RCC. There were 17 streaks on the left side and 4 on the right side. Samples of these streaks will be removed for laboratory analysis.

Orbiter windows 1 through 5 were hazed and residual matter adherred to windows 1 and 3.

The tires, wheels, and brakes were in good condition and were not a debris contributor, except for the previously mentioned tile damage caused by the wheel instrumentation debris. No tire or tile damage resulted from loose runway objects.

An infrared imaging system similar to the KSC Shuttle Thermal Imagers (STI) was used to record the thermal patterns of the Orbiter and estimate the kinetic surface temperatures of several areas. During the landing and rollout, the scanner was

equipped with a 10x telescope to permit closer inspection of the vehicle. Upon wheel stop, the scanner was moved to the 1250 foot convoy fall back position. Here, data collection continued with the 10x lens until clearance was given to move the scanner up to the Orbiter (approximately 1 hour after wheel stop) at which time the 10X lens was removed.

The RCC temperature values presented in Figure 20 were obtained with the infrared imaging system at the times noted. All readings were obtained by positioning the imager perpendicular to the surface of interest and averaging the values over a small area for statistical validity. The recorded temperatures were greatly influenced by the low ambient temperature (59 degrees F), time of day (just after sunup when solar heating is at a minimum), and strong head winds (increased convective cooling), which caused rapid temperature drops on the RCC nosecap and leading edge panels.

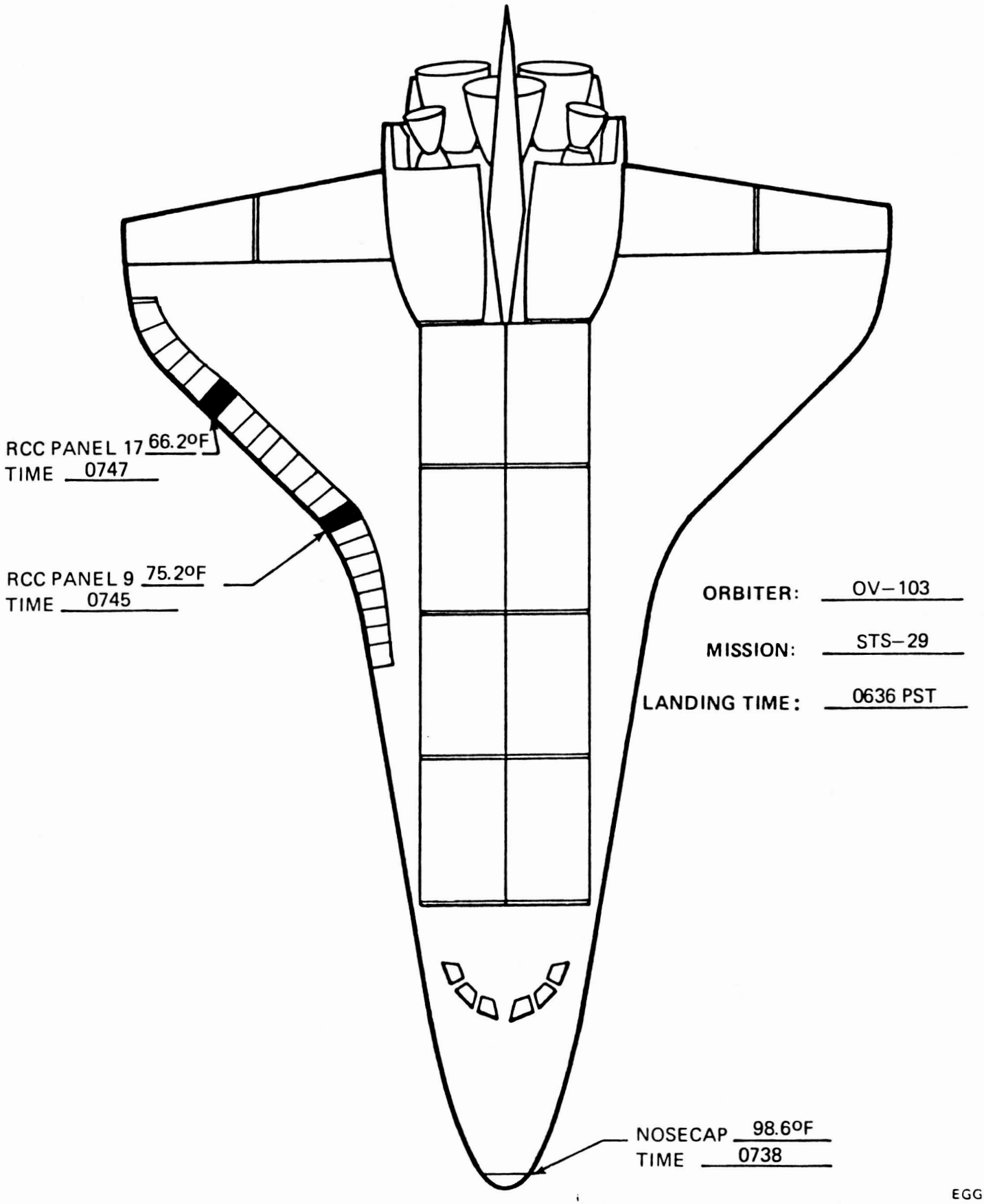
In summary, the total number of Orbiter TPS debris hits was average when compared to previous flights, as is shown in the comparison chart (Figure 21). Only 13 tiles will be pulled and replaced. There were 23 hits greater than 1 inch compared to the mission average of 30. The distribution of hits on the Orbiter does not point to a single source for debris, but indicates a shedding of ice and TPS debris from random sources.

Orbiter Post Launch Anomalies are listed in Section 10.0.

Date: 3–18–89

FIGURE 20

TEMPERATURE MEASUREMENTS



EGG/V–089D

FIGURE 21. STS-29R DEBRIS DAMAGE ASSESSMENT SUMMARY

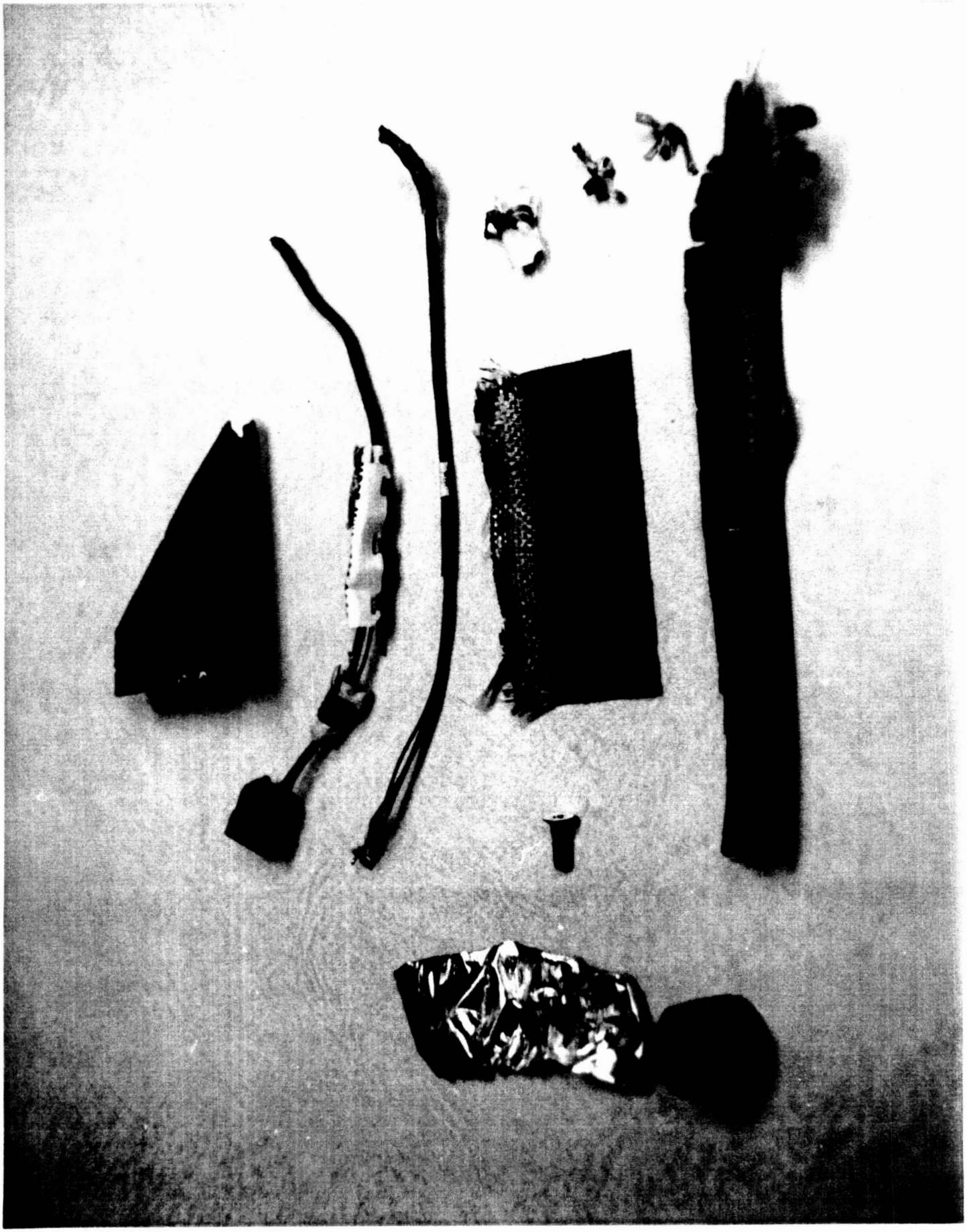
	Hits > or = 1"	Total Hits
Lower Surface	18	100
Upper Surface	1	5
Right Side	2	13
Left Side	0	6
Right OMS Pod	2	8
Left OMS Pod	0	0
TOTALS	23	132

COMPARISON TABLE

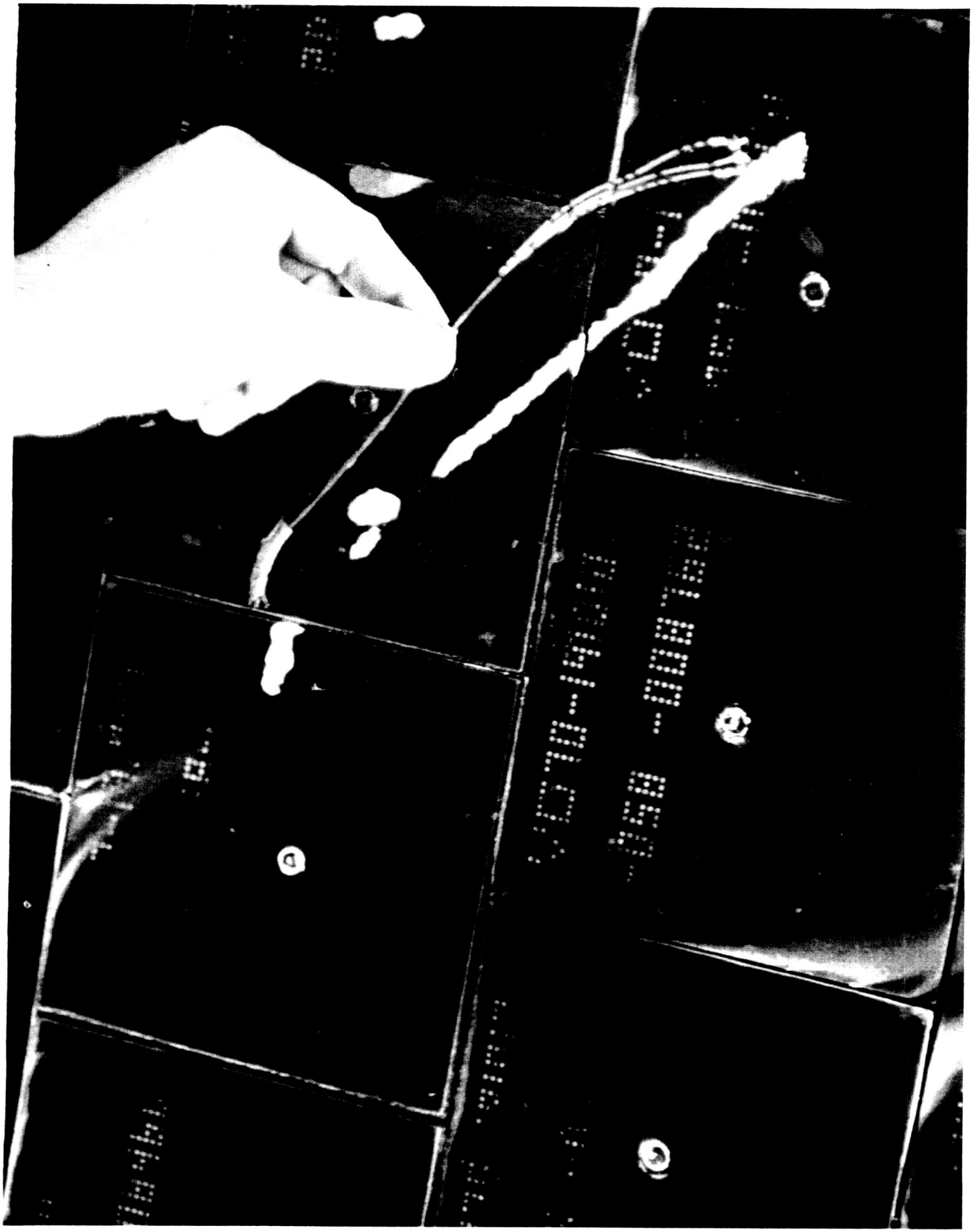
STS-6	36	120
STS-7	48	253
STS-8	7	56
STS-9 (41-A)	14	58
STS-11 (41-B)	34	63
STS-13 (41-C)	8	36
STS-14 (41-D)	30	111
STS-17 (41-G)	36	154
STS-19 (51-A)	20	87
STS-20 (51-C)	28	81
STS-23 (51-D)	46	152
STS-24 (51-B)	63	140
STS-25 (51-G)	144	315
STS-26 (51-F)	226	553
STS-27 (51-I)	33	141
STS-28 (51-J)	17	111
STS-30 (61-A)	34	183
STS-31 (61-B)	55	257
STS-32 (61-C)	39	193
STS-26R	55	411
STS-27R	298	707
STS-29R	23	132

DEBRIS COLLECTED DURING PRE-LANDING RUNWAY WALKDOWN

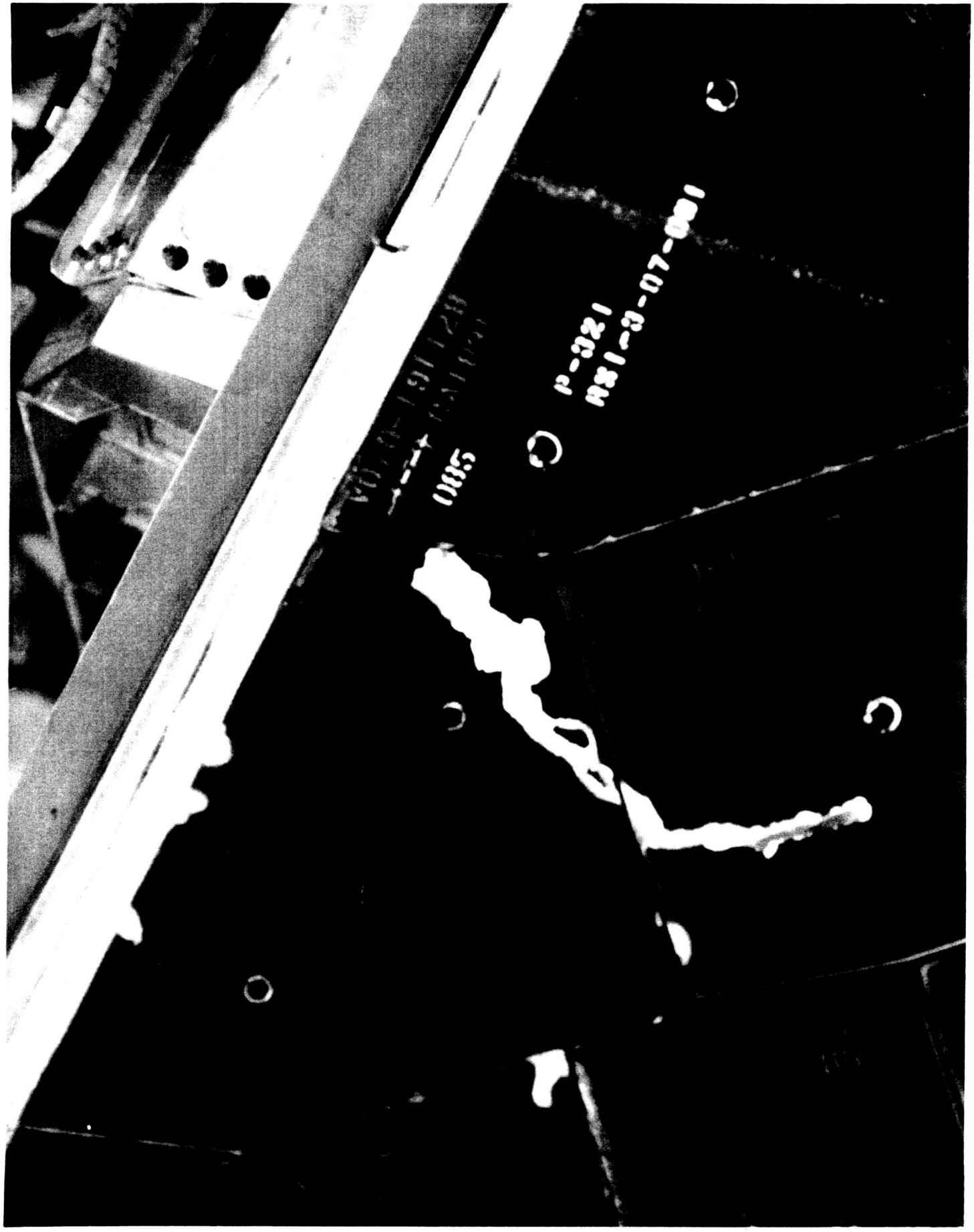
PIECE OF TILE FROM RH MLG DOOR FOUND NEAR RUNWAY THRESHHOLD



HARDWARE COLLECTED DURING POST LANDING RUNWAY WALKDOWN. NOTE TILE PIECE, AMES GAP FILLERS, AND WHEEL PRESSURE SYSTEM WIRES

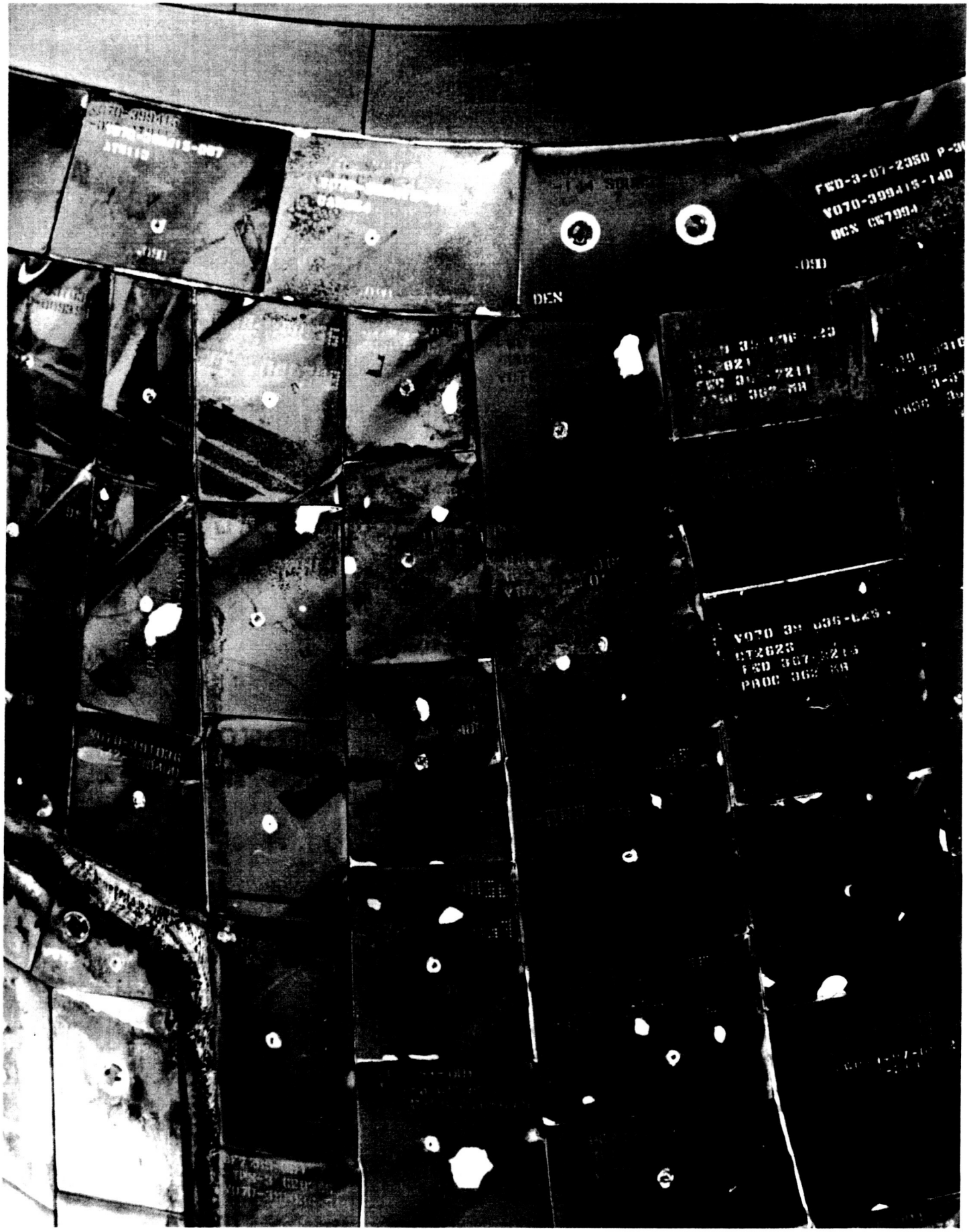


10-INCH GOUGE IN TILES AFT OF RH MLG DOOR DUE TO IMPACT
OF WHEEL PRESSURE STRAIN GAGE SYSTEM WIRE FOUND ON RUNWAY

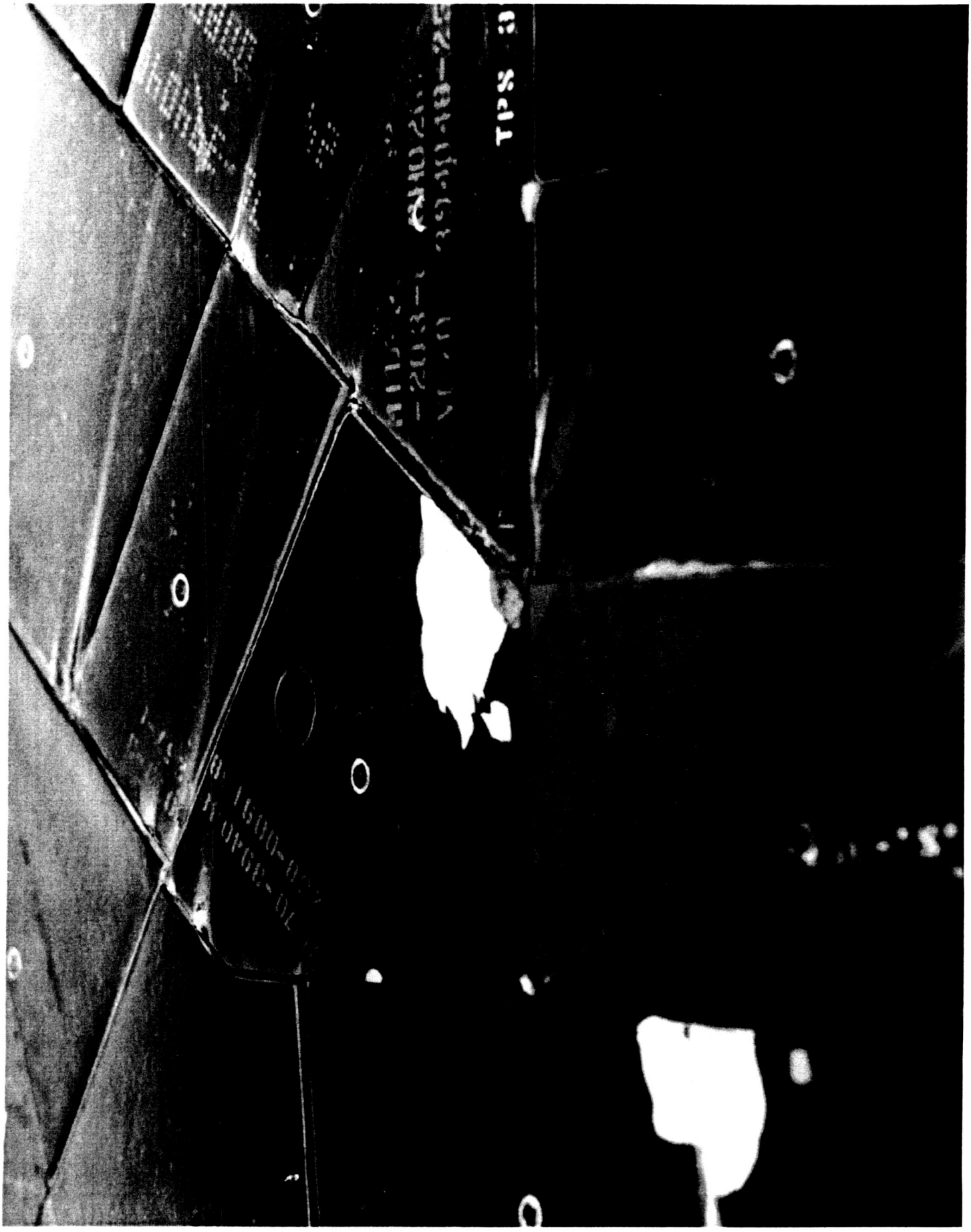


8"X1"X1-1/8" GOUGE AFT OF RH MLG DOOR DUE TO IMPACT OF WHEEL PRESSURE STRAIN GAGE SYSTEM WIRE/CONNECTOR FOUND ON RUNWAY

CLUSTER OF TILE HITS AFT OF ET/ORB LH2 UMBILICAL DUE TO UMBILICAL ICE PARTICLES RELEASED AT ET SEPARATION

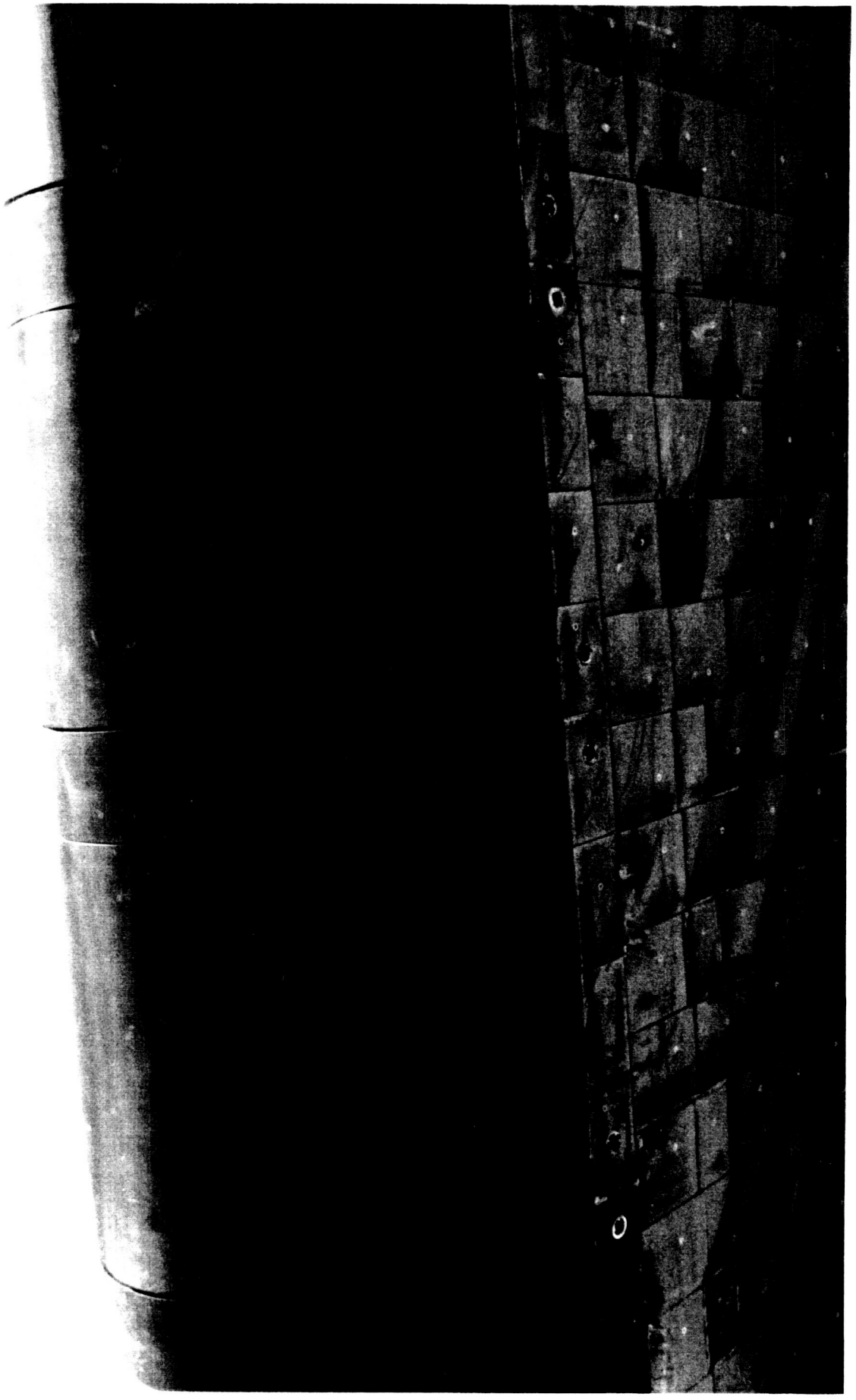


FUSELAGE TILE DAMAGE AFT OF ORBITER NOSE CAP

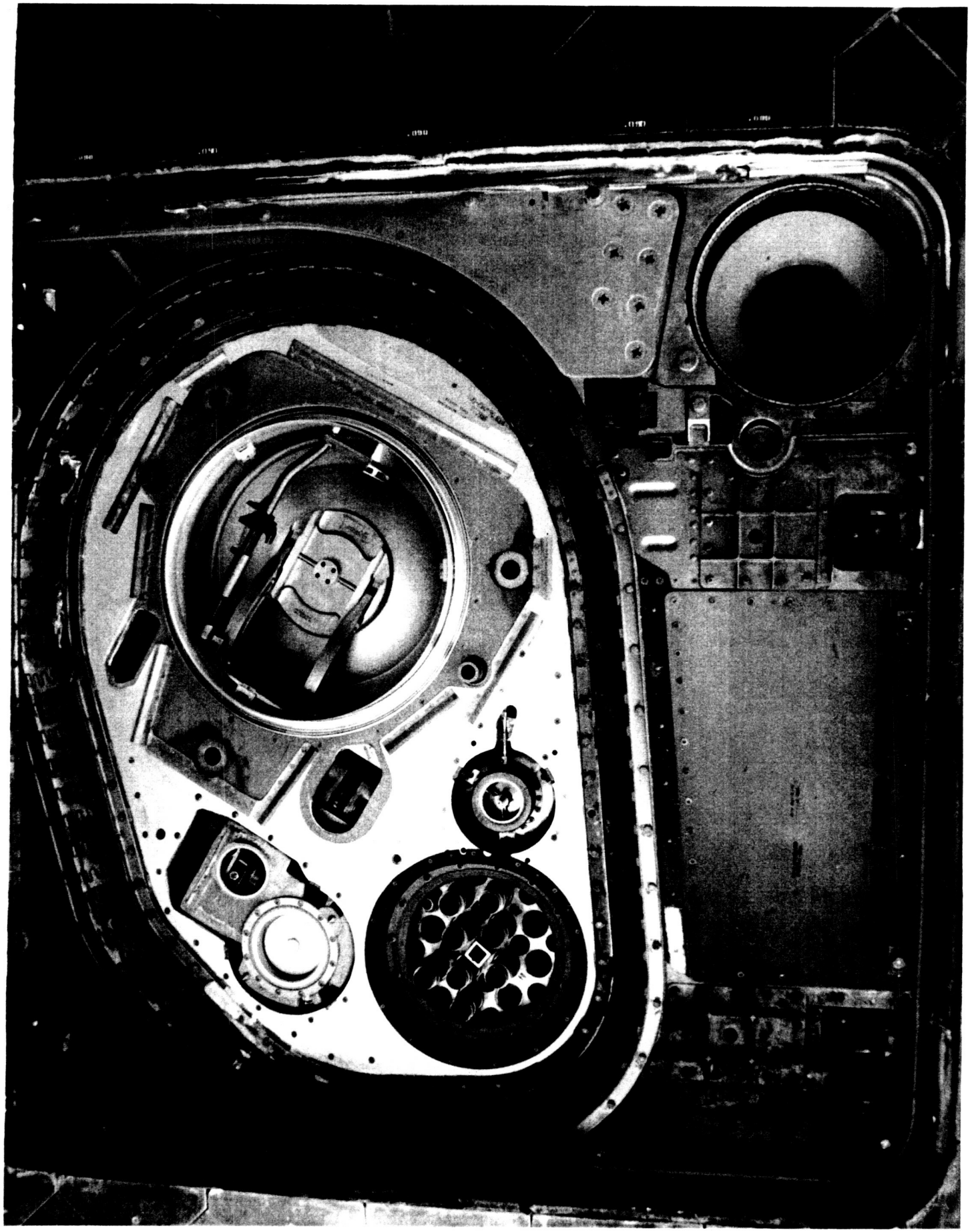


TYPICAL TILE DAMAGE FROM LOW DENSITY DEBRIS IMPACT

TYPICAL TILE DAMAGE FROM HIGH DENSITY DEBRIS IMPACT



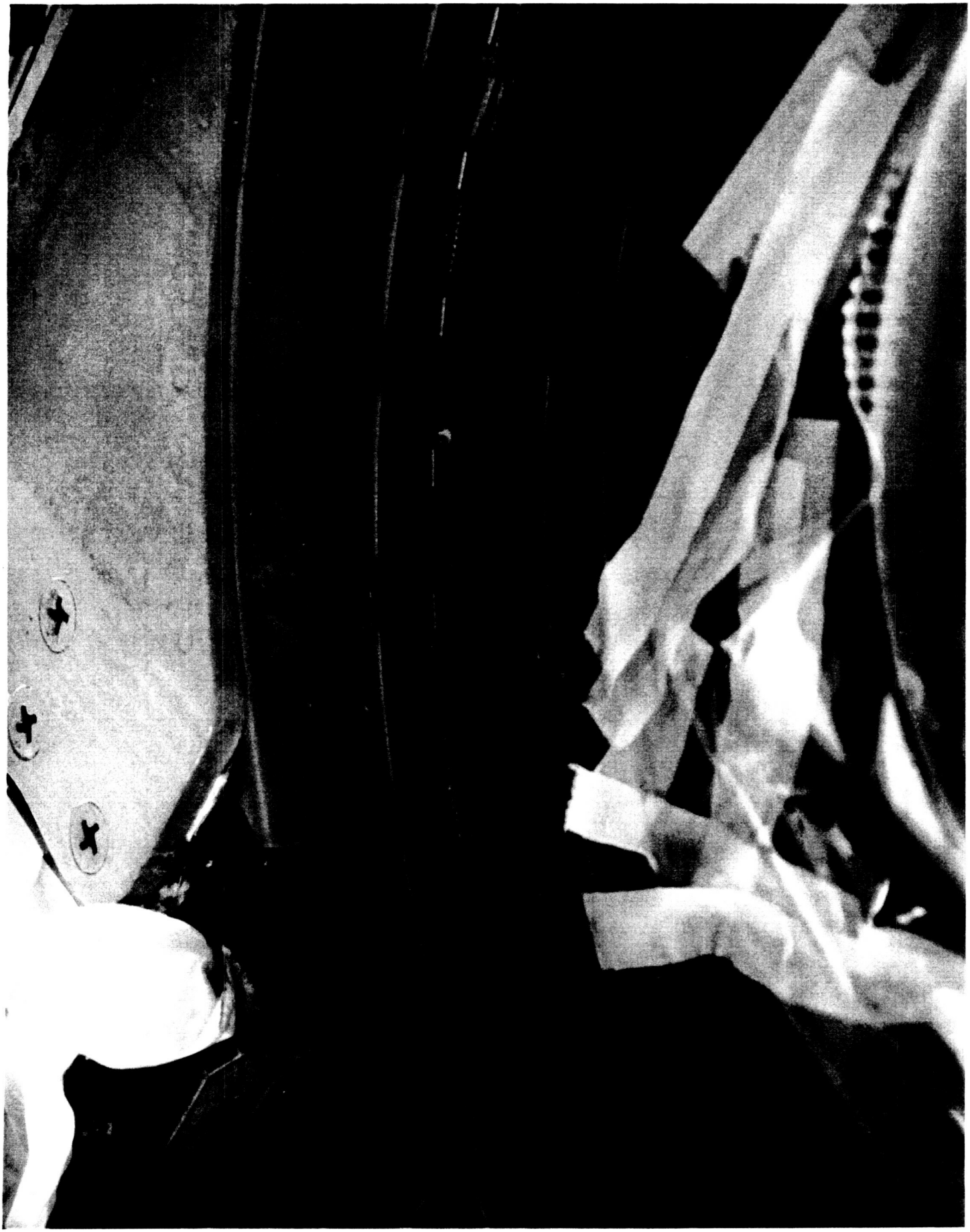
WHITE STREAKS ON WING LEADING EDGE RCC PANELS



NO SIGNS OF DAMAGE TO CRYOGENIC SEALS THAT WOULD CAUSE THE DENSE VAPORS TO EMANATE FROM LH2 UMBILICAL PRIOR TO LAUNCH

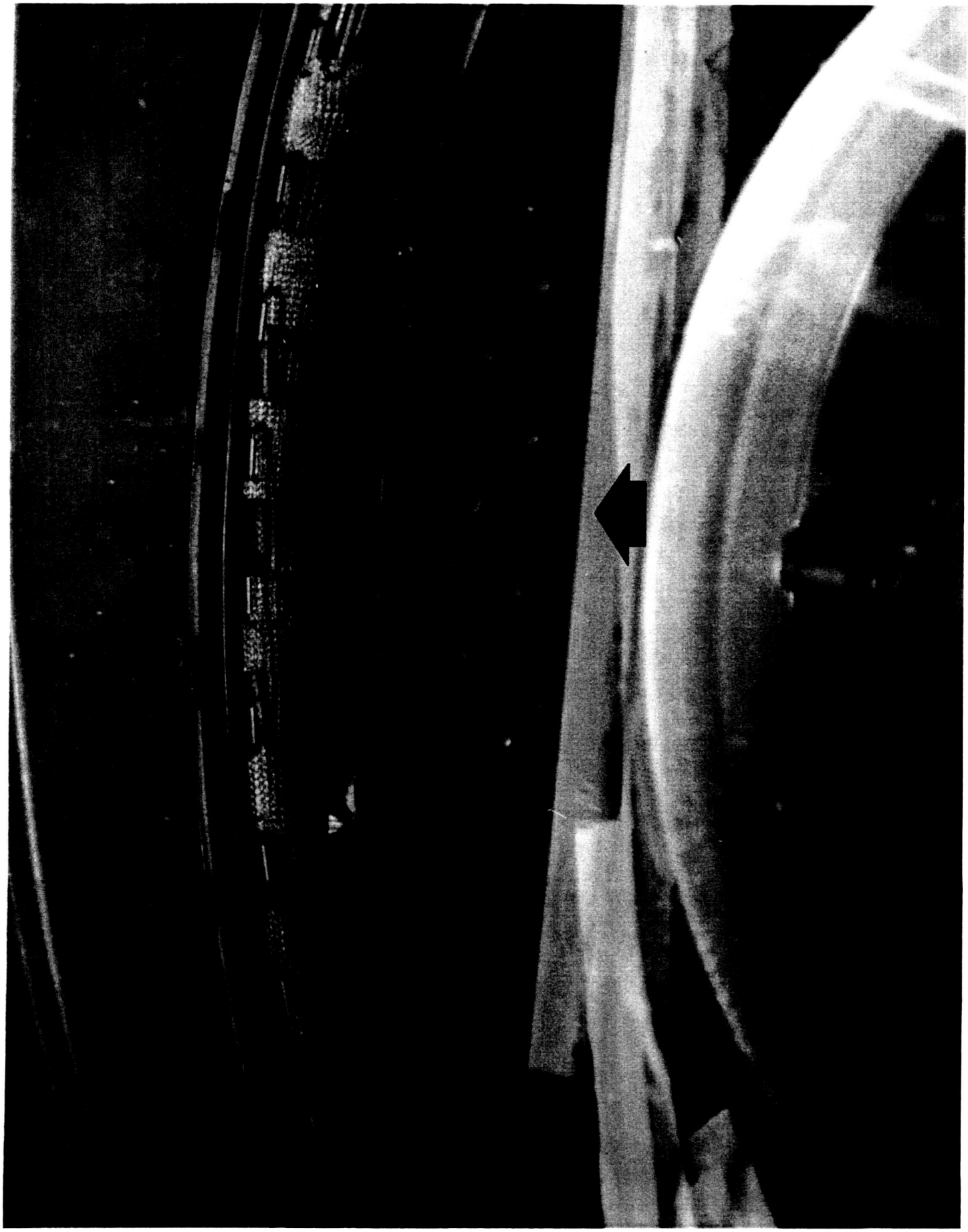
LO2 UMBILICAL 17-INCH DISCONNECT CREAVEY SEAL WAS FLATTENED ALONG A 1/2-INCH LENGTH

BOTH UMBILICALS EXHIBITED EXCESSIVE FOAM IN THE FLOW LEAK CHECK PORT CLOSEOUTS



SMALL PARTICLES OF SOFI IMBEDDED IN UMBILICAL SPRINGS

ORIGINAL PAGE
COLOR PHOTOGRAPH



FOREIGN MATERIAL RESIDUE DEPOSITED ON UMBILICAL PLATE

EO-2 SEPARATION FITTING DEBRIS PLUNGER JAMMED BY TWO LARGE PYROTECHNIC NUT FRAGMENTS

9.0 DEBRIS SAMPLE LAB REPORTS

A total of 37 samples were taken from orbiter OV-103 during post-landing debris assessment operations at Dryden Flight Research Facility, California. The 37 submitted samples consisted of dry wipes (10 from ORB wing, 1 scraper from wing leading edge); solvent (isopropyl alcohol) wet wipes (11 from wing leading edge, 1 solvent blank); ET/ORB umbilical samples (3 from LO2, 2 from LH2); adhering debris (3 from LH outboard body flap, 1 from LH wing RCC (tape residue); and tile samples (1 FWD, 2 MID and 2 from nose thruster area).

The samples were analyzed by the NASA-KSC Microchemical Analysis Branch (MAB) using optical microscopy (OM), infrared spectrometry (IRS), X-ray diffraction (XRD), and electron microprobe with energy dispersive spectrometry (EDS). These analytic methods identified the samples in chemical element data form. These sample data were compared to known Shuttle element material data references. The specific elemental analysis is shown in the Microchemical Analysis Branch report MCB 236-89.

A better understanding and presentation of the specific elemental analysis is attained when samples and results are grouped by orbiter location as shown in the following table and summary. Quantity of sample available for analysis contributes to understanding the reduced data. An indication of sample quantity is shown in the orbiter location table as T - trace/ small amount, or L - relatively large amount.

ORB LOCATION	SAMPLE	QUANTITY	AREA
FWD ORBITER	0279	L	Tile just aft of FWD down-firing RCS jets on left side
	0278	L	Tile on top of nose area just aft of nose thermal barrier
	2549	L	Tile on right side of FWD fuselage above nose landing gear
MID ORBITER	1247	L	Tile located on lower surface mid-fuselage along center line
	1246	L	Tile located on lower surface approx. 5-feet inboard of RH MLG door

LEFT WING	4A-1	T	RCC panel 9, dry wipe
(leading edge)	4A-2	T	RCC panel 8, dry wipe
	4A-3	T	RCC panel 9, dry wipe
	4A-4	T	RCC panel 16 T-seal 17, dry wipe
	4A-5	T	RCC panel 16, dry wipe
	4A-6	T	RCC panel 15, dry wipe
	4A-7	T	RCC panel 11, dry wipe
	4A-8	T	RCC panel 10, dry wipe
	4B-1	T	RCC panel 7, wet wipe
	4B-2	T	RCC panel 7, wet wipe
	4B-3	T	RCC panel 8, wet wipe
	4B-4	T	RCC panel 8, wet wipe
	4B-5	T	RCC panel 9, wet wipe
	4B-6	T	RCC panel 10, wet wipe
	4B-7	T	RCC panel 11, wet wipe
	4B-8	T	RCC panel 16, wet wipe
	4C		SOLVENT BLANK
	6	T	RCC panel 11, tape residue
RIGHT WING	scraper	T	Wing leading edge
(leading edge)	5A-1	T	RCC panel 19, dry wipe
	5A-2	T	RCC panel 18, dry wipe
	5B-1	T	RCC panel 18, solvent wipe
	5B-2	T	RCC panel 19, solvent wipe
	5C	T	RCC solvent wipe
ORB/ET	2A	L	LO2 umbilical, FWD cavity
UMBILICAL	2B	L	LO2 umbilical, spring
	2C	T	LO2 umbilical, baggie (tape)
	3A	L	LH2 umbilical, spring
	3B	T	LH2 umbilical, baggie (tpe)
BODY FLAP	1 (3 EA)	T	Residue on lower surface

Analysis of the five tile samples (FWD and MID ORB) revealed evidence of tile 'slumping' which is associated with re-entry heating. There was no evidence of high-temperature minerals in the tile samples. The absence of non-tile material in these samples suggests the cause of tile damage was not retained in the damage area or was tile material itself.

Wing sample analysis revealed appreciable amounts of tile materials, both black dense tile and white tile. Left wing samples from RCC panels 8 and 9 contained hypalon paint, RCC panels 11 and 15 contained microballoons identified as MSA-1 component, which is an SRB ablative material. Left and right wing samples contained RTV and SRB BSM residue-type material.

The ET-ORB umbilical cavity samples contained foam (polyurethane) that compares to that used on ORB, ET, and SRB. These cavity samples also contained microballoon, hypalon paint, tile materials, and SRB residue materials.

The ORB body flap sample contained Orbiter tile materials, hypalon paint, and other residue from the SRB.

Calcite, a naturally-found form of calcium carbonate, was found in the ET-ORB umbilical cavity and LH wing RCC panel 9 samples. A small amount of organic material, insufficient for identification-testing, was found in the ET/ORB LO2 umbilical cavity and on the LH and RH wing RCC panels. Salt and dust particles were found in the ET/ORB umbilicals, LH and RH wing, and MID-orbiter tile samples.

Results of this analyses also revealed two additional findings which are still under investigation:

The trace amounts of metallics (some of which had not experienced re-entry heating) found in ET/ORB umbilical cavity, left and right wings, and MID-fuselage tile samples.

The rust materials (carbon and stainless steel corrosion products) that were found in ET/ORB LO2 umbilical and LH wing samples.

An approximate 12-inch length of thin wire-like material was removed from the top of the LH Orbiter wing during post landing operations in the Mate/Demate Device. The wire material was submitted to the NASA-KSC Microchemical Analysis Branch for identification testing. Results, MAB report MCB 257-89, indicate the wire is a rolled carbon steel tube with a metallic aggregate core. Material analysis testing indicates the wire is a carbon steel flux cored welding electrode (welding wire). The analytical results and removal location (no Orbiter surface penetration) indicate the welding wire material source was the Mate/Demate Device.

10.0 POST LAUNCH ANOMALIES

A total of 30 Post Launch Anomalies were observed for STS-29R.

10.1 EXTERNAL TANK

Four anomalies were observed for the STS-29R External Tank (ET-36).

The first ET anomaly concerns the dense vapor and cryogenic liquid emanating from the LH2 ET/Orbiter umbilical during LH2 fast fill. Assessment by the Ice Team and Launch Management Team concluded that there was no LH2 leakage and that the cryogenic fluid was most probably liquid air caused by a crack in the umbilical TPS, which resulted in a thermal short.

As the GUCP separated from the vehicle at liftoff, small pieces of ET intertank foam were pulled loose from the RH side of the GUCP plate cutout. This anomaly was observed during launch film review.

Inspection of the ET on-orbit photography revealed the bipod struts had not folded forward as designed. They remained in the extended position after separation from the Orbiter.

The fourth ET anomaly was also discovered upon inspection of the ET on-orbit photography taken by the flight crew. Analysis of these photos revealed a 6-inch divot in the +Y longeron TPS where a previous vendor repair existed. Five divots ranging in size from 14 to 20 inches in diameter occurred in the -Y thrust panel and along the intertank-to-LH2 tank flange/ acreage ramp closeout. Numerous smaller divots were detected along both LH2 and LO2 tank to intertank flange closeouts. These divots are a considerable debris concern.

10.2 SOLID ROCKET BOOSTERS

Eighteen anomalies were observed for the Solid Rocket Boosters (BIO-31) flown on STS-29R.

The first concerns the numerous MSA debonds found on the SRB frustums during the SRB post flight inspection. Fifty-one debonds were detected on the RH SRB frustum and 31 debonds were found on the LH SRB frustum. These debonds represent potential debris sources.

The -Z RSS antenna forward ramp lost a 6-1/2" x 5-1/8" piece of SLA 220 TPS with clear signs of adhesive failure on the substrate. This anomaly was noted during the post flight inspection.

The loss of instafoam from the SRB aft skirts continues. Films from this and numerous prior STS missions have shown that a large quantity of instafoam is lost at liftoff during ascent.

Holddown post epon shim material was lost from the SRB aft skirts in 6 areas. Post #3 lost two pieces of shim (3-inch dia and 1-1/2" x 3/4"), post #4 lost two pieces (15" x 3-1/2" and 3" x 2"), and post #8 lost two pieces (12" x 2" and 6" x 3").

The fifth SRB anomaly concerns the loss of GEI MSID epoxy covered labels from both SRBs. Post flight inspection revealed that numerous labels were either partially or completely missing.

A large K5NA cable closeout on the RH SRB FWD segment XB 850 (90 degrees) contained several cracks. This closeout had exceeded the allowable protuberance limit.

K5NA was lost from around all eight BSM nozzles. The loss of this material was noted during the post flight inspection and has occurred on many previous missions.

Two factory joint EPDM weather seals were debonded on the LH SRB - one on the FWD center segment case at XB 1011.5 (180 degrees) and the second on the aft center segment case at XB 1331.5 (90-270 degrees).

The ninth anomaly concerns the blistering and loss of both white and black Hypalon paint from the SRB frustums. These blisters ranged in size from 1/8-inch to 5-inches in the black areas and 1/8-inch to 1/2-inch in the white areas. Some of the blisters had MSA-2 (a new type of ablator) attached to the paint. This phenomenon has occurred on previous missions.

Four of the eight aft skirt holddown post debris containers did not function properly. Numerous pieces of NSI cartridge and frangible nut were lost from holddown posts #2, 4, 7, and 8.

Voids/debonds were discovered in the nozzle glass phenolic-to-aluminum shell bondline during SRB disassembly. MTI stated the nozzle unbonds are not a problem, but accepted the action to investigate this anomaly.

The pressure transducer ramps on the LH SRB exhibited multiple TPS (cork) debonds. No material was missing.

Numerous divots in the aft skirt field joint DFI cork closeouts were examined during the post launch inspection. Some divots in this area were sooted, an indication of ascent heating (reference PRs PV-6 124965 and 124967).

For STS-29R, the SRB nozzle extensions were severed at apogee instead of the usual time after parachute deployment and just prior to water impact. This change permitted greater heating

under the aft skirt causing the more-than-usual loss of aft skirt instafoam. This, in turn, subjected both TVC systems to severe heat and water impact damage.

The fifteenth SRB anomaly concerned the aft skirt thermal curtain tape. Launch film analysis showed that numerous pieces of tape were partially loose at liftoff.

Post flight SRB disassembly revealed the RH SRM igniter sustained a putty blowhole at approximately 300 degrees. This is an expected condition according to MTI.

Five gallons of sea water had entered both the RH and LH forward skirts during splashdown/recovery operations. The intrusion of sea water into the forward skirt has occurred on several previous flights.

The eighteenth SRB anomaly concerns damage to a field joint capture feature o-ring discovered during disassembly. One possible cause of the damage may be attributed to scrape marks from raised metal on adjacent surfaces due to cold welding (fretting) typically encountered during the disassembly process.

10.3 ORBITER

Six STS-29R Orbiter anomalies were observed for OV-103 (Discovery).

A 3-1/2" x 2-3/4" piece of the outboard-forward corner tile from the RH main landing gear door broke loose upon gear deployment. This tile piece was recovered near the runway threshold during the post landing runway inspection.

The second Orbiter anomaly involved the loss of tile gap fillers and Q-felt plugs at launch and landing. Six tile gap fillers and one Q-felt plug fell from the Orbiter in the launch films. Three Q-felt plugs were found within the pad perimeter after launch and two gap fillers were recovered on the runway following Orbiter landing.

Two 10" long pieces of wire, one with a connector attached, were recovered during the post landing runway inspection. These wires came from the RH main landing gear wheel pressure strain gage system. The wires became detached during wheel spin-up at touchdown and impacted the Orbiter lower surface.

During the post landing inspection, a GSE bolt was found where the baggie attaches to the structure on the ET/ORB LO2 umbilical. It was located on the inboard side of the umbilical, at approximately the 7 o'clock position. (12 o'clock being forward).

The fifth Orbiter anomaly was discovered during the post landing inspection. The debris plunger in the RH (LOX) EO-2 separation fitting debris container failed to seat properly in the 2-1/2" hole at ET/ORB separation. The plunger was jammed by two large pyro nut fragments. This plunger is listed as a Criticality I item due to the possibility of loose debris exiting the debris container and causing the ET door hinge/latching mechanism to fail.

In addition to the EO-2 separation fitting debris container plunger failure, two of the LO2 umbilical separation bolt debris container plungers did not have total closure. Both of these plungers were also jammed by pyro fragments.

10.4 FACILITY

Two anomalies were attributed to the launch pad/facility for this mission.

The first facility anomaly concerns two metal electrical receptacle covers and a terminal box door for a MLP/Portable Purge Unit (PPU) interface that were found at the pad perimeter after launch. These items were blown from the MLP deck at launch and are debris sources.

The second observed facility anomaly was discovered during the post launch pad debris inspection. Two emergency egress slidewire baskets were released after the vehicle cleared the tower.

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1,ROOM 1274,0&C BUILDING
NASA/KSC
April 18, 1989

SUBJECT: Residues from Body Flap and Wing RCC Panels, and Tape from L/H Wing RCC

LABORATORY REQUEST NO: MCB 236-89

RELATED DOCUMENTATION: Intercenter debris team Reqm'ts.

1.0 FOREWORD:

1.1 REQUESTER: R. F. Speece/TV-MSD-22/7-0806

1.2 REQUESTER'S SAMPLE DESCRIPTION:

The samples were removed from OV-103, mission STS-29R landing, DFRF. The samples were identified as follows:

Sample #1: TPS RSI 3-09-133, P/N VO70-395016-186, 187 and 188.

Sample #2A: LO2 unbilical FWD of umbilical RSI 3-09-133

Sample #2B: LO2 umbilical, LO2 umbilical spring, RSI 3-09-133

Sample #2C: LO2 umbilical, LO2 baggie (tape), RSI 3-09-133

Sample #3A: LH2 umbilical, LH2 umbilical spring, RSI 3-09-133

Sample #3B: LH2 umbilical, LH2 baggie (tape), RSI 3-09-133

Sample #4A-1: L/H RCC panels, RSI 3-09-133, circular grit, panel #9, dry wipe.

Sample #4A-2: L/H RCC panel, RSI 3-09-133, panel #8, dry wipe

Sample #4A-3: L/H RCC panel, RSI 3-09-133, panel #9, dry wipe

Sample #4A-4: L/H RCC panel, RSI 3-09-133, panel #16.T seal 17, dry wipe

Sample #4A-5: L/H RCC panel, RSI 3-09-133, panel #16, dry wipe

Sample #4A-6: L/H RCC panel, RSI 3-09-133, panel #15, dry wipe

Sample #4A-7: L/H RCC panel, RSI 3-08-133, panel #11, dry wipe

Sample #4A-8: L/H RCC panel, RSI 3-09-133, panel #10, dry wipe

Sample #4B-1: L/H RCC panel, RSI 3-09-133, panel #7, wet wipe

Sample #4B-2: L/H RCC panel, RSI 3-09-133, panel #7, wet wipe

Sample #4B-3: L/H RCC, RSI 3-09-133, panel #8, wet wipe

Sample #4B-4: L/H RCC, RSI 3-09-133, panel #8, wet wipe.

Sample #4B-5: L/H RCC, RSI 3-09-133, panel #9, wet wipe

Sample #4B-6: L/H RCC, RSI 3-09-133, panel #10, wet wipe

Sample #4B-7: L/H RCC, RSI 3-09-133, panel #11, wet wipe

Sample #4B-8: L/H RCC, RSI 3-09-133, panel #16, wet wipe

Sample 4C: Solvent blank, IPA, L/H RCC, RSI 3-09-133

Sample Scraper: RSI 3-09-133, dry wipe only

Sample 5A-1: R/H RCC, RSI 3-09-133, panel #19, dry wipe

Sample 5A-2: R/H RCC, RSI 3-09-133, panel #18, dry wipe

Sample 5B-1: R/H RCC, RSI 3-09-133, panel #18, solvent wipe

Sample 5B-2: R/H RCC, RSI 3-09-133, panel #19, solvent wipe

Sample 5C: R/H RCC, RSI 3-09-133, IPA solvent blank

Sample #6: L/H RCC, RSI 3-09-133, panel #11, tape residue

PR MID 3-09-1247: OCN 000779, tile, VO70-394026-099

PR MID 3-09-1246: OCN 008768, VO70-394028-144

PR FWD 3-09-2549: OCN F07137 VO70-391015-043

PR TFRC 3-09-0279: VO70-391005-179

PR TFRC 3-09-0278: VO70-3-91003-219

1.3 REQUESTED:

Identify composition and reentry affects

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 Procedures:

The submitted samples were analyzed by means of Optical Microscopy (OM), Infrared Spectrometry (IRS), X-ray Diffraction (XRD) and electron microprobe with energy dispersive spectrometry (EDS).

2.2 Results:

2.2.1 The particulates were classified into components on the basis of color and texture by OM. The classified components from all samples are listed in Table 1 with the possible identification of each component and elemental analysis.

Table 1

Component ID	Possible ID	Elemental Analysis by EDS Major	Minor
1. Metallics	Ag,Zn,Al,Cd,metals, SS,Carbon steel	Ag,Zn,Al,Cd, Fe,Cr	Ni
2. White mtls	White tile	Si	
3. Blk dense mtls	Black tile	Si	
4. Wht glossy mtls	paint	Ti	Al,Si,Mg,Fe, Ca
5. Glass fiber	Insulation glass	Si,Ca	Al,Mg,Ti
6. Lgt. grey mtls	Calcite	Ca	
7. Organic foam	Polyurethane		
8. Amber sphere	Microballoon		
9. Blk sphere	C- steel or Fe,Ti, Cl,Sb,mtls	Fe,Ti,Cl,Sb	Zn,S,P,Si, Al
10. Blk flakes	Mg,Si,flake	Mg,Si	S,Cl,Ca,Ti Fe,K
11. Yellow mtls	Yellow Si,Al,Ca,Pb, mtls	Si,Al,Ca,org.	Fe,Sb
12. Red rubbery	RTV	Fe,Si	
13. Red mtls	Rust	Fe,	Si,Al,Cl,K, Ca,Cr
14. Blk mtls	Dust & Salt	Ca,Si,Fe,Ti	Al,S,Cl,K,Zn,

		Pb	Sb
15. Shiny amber flake	Fe,Si,K,Al,flake	Fe,Si,K,Al	Ti,Mg,Mn,Ca
16. White powdery	White Ca,Si,Al,mtls	Ca,Si,Al	Zn

2.2.2 Table 2 lists estimated amounts of each component versus sample number.

Table 2

Sample No.	#1	2A	2B	2C	#3A	3B	4A-1
Amount of Sample	S	L	L	S	L	S	S
1. Metallics	X	X	X	Ag,Zn,Al	X	Al,Cd	X
2. Tile	57	X	X	20	X	T	100
3. Paint	30	X	X	T	X	X	X
4. Insulation glass	3	X	X	T	X	T	T
5. Calcite	X	X	20	20	T	35	T
6. Polyurethane Foam	X	X	X	50	100	60	X
7. Microballoon	X	X	X	T	X	2	X
8. C-Steel sphere	X	X	X	T	X	T	X
9. Mg, Si, flakes	X	X	X	X	T	X	X
10. Yellow Ca,Si,Al	X	X	X	X	X	T	X
11. RTV	X	X	X	X	X	X	T
12. Organics	X	100	80	X	X	X	X
13. Rust	X	T	T	5	X	X	X
14. Dust & Salt	X	T	T	5	X	T	X
15. Fe,Si,K,Al, Flake	10	X	X	X	X	X	X
16. White Ca,Si,Al,mtls	X	X	X	X	X	X	X
17. Yellow Pb,Cl,Si	X	X	X	X	X	X	X
18. Alpha- Cristobalite	X	X	X	X	X	X	X
Total	100	100	100	100	100	100	100

X: not detected
Ag, Zn, Al, Cd, metals

Table 2 Cont'd

Sample No	4A-2	4A-3	4A-4	4A-5	4A-6
Amount of Sample	S	S	S	S	S
1. Metallics	Ag	X	X	X	X
2. Tile	90	90	60	70	95
3. Paint	T	T	X	X	X
4. Insulation glass	X	X	X	T	X
5. Calcite	X	X	X	X	X
6. Foam	X	X	X	X	X
7. Microballoon	X	X	X	X	T
8. C-steel sphere	X	X	X	X	X
9. Mg, Si flakes	X	X	X	X	X
10. Yellow Ca,Si,Al	X	X	40	X	X

11. RTV	T	X	X	X	X
12. Organics	10	10	X	X	5
13. Rust	X	X	T	X	X
14. Dust & Salt	T	T	T	X	X
15. Fe,Si,K,Al, flake	X	X	X	30	X
16. White Ca,Si,Al mtls	X	X	X	X	X
17. Yellow Pb,Cl,Si	X	X	X	X	X
18. Alpha-cristobalite	X	X	X	X	X
Total	100	100	100	100	100

X: Not detected
Ag, metal

Table 2 Cont'd

Sample No.	4A-7	4A-8	4B-1	4B-2	4B-3	4B-4
Amount of Sample	S	S	S	T	T	T
1. Metallics	X	X	Al,SS	X	X	X
2. Tile	100	100	90	100	X	90
3. Paint	X	X	X	X	X	X
4. Insulation	X	X	X	X	X	X
5. Calcite	X	X	X	X	X	X
6. Polyurethane Foam	X	X	X	X	X	X
7. Microballoon	T	X	X	X	X	X
8. C-steel sphere	X	X	X	X	X	X
9. Mg,Si, flakes	X	X	X	X	X	X
10. Yellow Ca,Si,Al	X	X	X	X	X	X
11. RTV	X	T	X	X	X	T
12. Organics	T	X	X	T	100	X
13. Rust	X	T	X	X	X	X
14. Dust & Salt	T	T	T	X	X	X
15. Fe,Si,K,Al, Flake	X	X	10	X	X	X
16. White Ca,Si,Al,mtl	X	X	X	T	X	X
17. Yellow Pb,Cl,Si	X	T	X	X	X	10
18. Alpha-cristobalite	X	X	X	X	X	X
Total	100	100	100	100	100	100

X: Not detected
Al, metal, SS: Stainless steel (300 series)

Table 2 Cont'd

Sample No.	4B-5	4B-6	4B-7	4B-8	Scraper	4C
Amount of Sample	T	T	T	T	T	No
1. Metallics	Cd	X	X	X	X	X
2. Tile	13	90	86	80	X	X
3. Paint	X	X	X	X	X	X
4. Insulation	X	X	X	X	X	X
5. Calcite	X	X	X	X	X	X
6. Polyurethane Foam	X	X	X	X	X	X
7. Microballoom	X	X	X	X	X	X
8. C-steel sphere	X	X	X	X	X	X
9. Mg, Si, Flakes	X	X	X	X	X	X
10. Yellow Ca,Si,Al	X	T	X	X	X	X
11. RTV	T	X	T	X	X	X
12. Organics	X	10	10	X	100	X
13. Rust	7	X	X	X	X	X
14. Dust & Salt	70	T	X	T	X	X
15. Fe,Si,K,Al, flake	X	X	4	20	X	X
16. White Ca,Si,Al,mtl	20	X	X	X	X	X
17. Yellow Pb,Cl,Si	X	X	X	X	X	X
18. Alpha-cristobalite	X	X	X	X	X	X
Total	100	100	100	100	100	

X: Not detected
Cd, metal,

Table 2 Cont'd

Sample No.	5A-1	5A-2	5B-1	5B-2	5C	#6
Amount of Sample	S	S	S	S	S	S
1. Metallics	Fe,Zn	Fe-Zn	X	X	X	X
2. Tile	5	30	80	95	5	X
3. Paint	X	X	X	X	X	X
4. Insulation	T	T	X	T	X	T
5. Calcite	X	X	X	X	X	X
6. Polyurethane Foam	X	X	X	X	X	X
7. Microballoom	X	X	X	X	X	X
8. C-steel sphere	X	X	X	X	X	X
9. Mg,Si, flakes	X	X	X	X	X	X
10. Yellow Ca,Si,Al	T	X	X	X	X	X
11. RTV	T	T	T	T	T	X
12. Organics	15	15	10	3	80	15
13. Rust	X	X	X	X	X	X
14. Dust & Salt	80	55	10	2	15	14
15. Fe,Si,K,Al, flake	X	X	X	X	T	66
16. White Ca,Si,Al,mtls	X	X	X	X	X	5
17. Yellow Pb,Cl,Si	X	X	X	X	X	X
18. Alpha-cristobalite	X	X	X	X	X	X
Total	100	100	100	100	100	100

X: Not detected
Fe, Zn, metals, Fe-Zn alloy

Table 2 Cont'd

Sample No.	1247	1246	2549	0279	0278
Amount of Sample	L	L	L	L	L
1. Metallics	Al	X	X	X	X
2. Tile	100	100	100	100	100
3. Paint	X	X	X	X	X
4. Insulation	X	X	X	X	X
5. Calcite	X	X	X	X	X
6. Polyurethane Foam	X	X	X	X	X
7. Microballoon	X	X	X	X	X
8. C-steel sphere	X	X	X	X	X
9. Mg,Si, flakes	X	X	X	X	X
10. Yellow Ca,Si,Al	T	X	X	X	X
11. RTV	X	X	X	X	X
12. Organics	X	X	X	X	X
13. Rust	X	X	X	X	X
14. Dust & Salt	T	X	X	X	X
15. Fe,Si,K,Al, Flake	T	T	T	X	X
16. White Ca,Si,Al,mtls	X	X	X	X	X
17. Yellow Pb,Cl,Si	X	X	X	X	X
18. Alpha-cristoballite	X	T?	T?	T	X
Total	100	100	100	100	100

X: Not detected
Al - metal

2.2.3 Figures 1 and 2 are scanning electron microscopy (SEM) photomicrographs of amber colored microballoon to show the morphological features of those hollow spheres.

2.2.4 Figures 3 and 4 are low magnification SEM photomicrographs of black tile debris to show the surface characteristics.

2.2.5 Figure 5 is low magnification SEM photomicrograph of the white clear materials on the black tile surface to show the mud-crack pattern of cracks.

2.2.6 Figure 6 is low magnification SEM photomicrograph of the white haze deposits on the black tile surface. Some of the white clear and white haze deposits were identified to be alpha-cristobalite (SiO2).

2.2.7 Figure 7 is SEM photomicrograph of the crusty grey materials from sample number 0279.

3.0 CONCLUSIONS:

3.1 The sample numbers 1, 2C, 3B, 4A-1 through 4A-8. 4B-1 through 4B-8, Scraper, 5A-1, 5A-2, 5B-1, 5B-2, 5C and 6 contained trace to small amounts of particles. The sample numbers 2A, 2B, 3A, 1247, 1246, 2549, 0279 and 0278 contained large amounts of sample.

3.2 The sample numbers 2C, 3B, 4A-2. 4B-1. 5A-1, 5A-2, and 1247 contained trace amounts of metallics. The metallics are composed of a combination of Ag-, Zn-, Al-, Cd , metals, a 300 series stainless steel, carbon steel and Fe - Zn alloy.

3.3 The sample numbers 1, 2C, 3B, 4A-1 through 4A-8, 4B-1, 4B-2, 4B-4, 4B-5, 4B-6, 4B-7, 4B-8, 5A-1, 5A-2, 5B-1, 5B-2, 5C, 1247, 1246, 2549, 0279 and 0278 contained appreciable amounts of tile materials. The tiles were composed of black dense tile and white tile.

3.4 The tiles from the sample # 1246 are composed of a white tile, black tile and crusty grey granular tile. Some particles of black tile surface contained white clear glassy materials. The OM and XRD data suggested that some of these particles were composed of poorly crystallized cryptocrystalline materials and alpha-cristobalite, crystalline silica caused by high temperature (1470 degrees C). The poorly crystallized cryptocrystalline silica could be formed from high temperature.

3.5 The black outer top surfaces of tiles from the sample numbers 2549 and 0279 show white haze deposits. The XRD data indicated to be alpha-cristobalite. Some of the black tile surfaces from sample number 0278 were covered with crusty light grey materials. Those materials were optically poorly crystallized cryptocrystalline materials which might be formed at high temperature.

3.6 Some particles of black tile show fused or melted or resolidified appearance. No evidence of high temperature forms of minerals was noted from these particles.

3.7 The sample numbers 1, 2C, 4A-2, and 4A-3 contained small amounts of white glossy paint particles.

3.8 The sample numbers 1, 2C, 3B, 4A-1, 4A-5, 5A-1, 5A-2, 5B-2, and #6 contained small amounts of glass fibers. The glass fibers were identified to be a combination of insulation and high temperature Al, Si, B glass.

3.9 The sample numbers 2B, 2C, 3A, 3B, and 4A-1 contained white colored powdery calcite.

3.10 The sample numbers 2C, 3A, and 3B contained black to white colored foam. The IRS data indicated that the foam particles from all samples were identified to be polyurethane.

The foam from samples #2 and #3-B were very similar to cardboard pail of foam labelled "PDL (type of foam)", "BX250" and "Insta foam". The foam from sample #3A yield an IR spectra resembling the "CPR" and "NCFI 22-65", and two other particles were very similar to "insta-foam", "BX-250" and "PDL" foam. The light amber orange colored tapes were identified to be polyimide such as Kapton - acrylate based adhesive.

3.11 The sample numbers 2C, 3B, 4A-6, and 4A-7 contained microballoon. The morphology and color of these microballoons appeared to be very similar as one of the components of MSA-1.

3.12 The sample numbers 2C and 3B contained black carbon steel spheres.

3.13 The sample number 3A contained trace amounts of black Mg, Si rich flakes. The OM data suggested that this material was composed of poorly crystallized crypto-crystalline materials which were not detectable by XRD technique.

3.14 The sample numbers 3B, 4A-4, 4B-6 and 5A-1 contained yellow colored either Ca,Si, Al rich or Si, Ca, Al, Pb rich materials. These materials are not identified due to small amounts of sample.

3.15 The sample numbers 4A-1, 4A-2, 4A-8, 4B-4, 4B-5, 4B-7, 5A-1, 5A-2, 5B-1, 5B-2, and 5C contained trace amounts of room temperature vulcanizing (RTV) rubber.

3.16 The sample numbers 2A, 2B, 4A-2, 4A-3, 4A-6, 4A-7, 4B-2, 4B-3, 4B-6, 4B-7, Scraper, 5A-1, 5A-2, 5B-1, 5B-2, 5C, and 6 contained organic materials. The organic components were not identified at this time. Some of the samples contained small amounts of organic fibers.

3.17 The sample numbers 2A, 2B, 2C, 4A-4, 4A-8, and 4B-5 contained rust materials. The rust materials appeared to be composed of corrosion products of carbon steel and stainless steel.

3.18 The sample numbers 2A, 2B, 2C, 3B, 4A-2, 4A-3, 4A-4, 4A-7, 4A-8, 4B-1, 4B-5, 4B-6, 4B-8, 5A-1, 5A-2, 5B-1, 5B-2, 5C, 6, and 1247 contained a combination of salt and dust particles.

3.19 The sample numbers 1, 4A-5, 4B-1, 4B-7, 4B-8, 5C, 6, 1247, 1246, and 2549 contained light orange colored shiny flakes. These flakes contained major Fe, Si, K, Al with minor Ti, Mg, Mn and Ca

3.20 The sample numbers 4B-2. 4B-5, and 6 contained white colored Ca, Si, Al rich materials. The sample was not analyzed by XRD due to small amounts of sample.

3.21 The sample numbers 4A-8 and 4B-5 contained yellow

colored Pb, Cl, Si, rich materials.

3.22 The samples were attached with this report.

CHEMIST: H. S. Kim
H. S. Kim

APPROVED: J. F. Jones
J. F. Jones

Figure 1
SEM Photomicrograph of Microballoom, 4A-6
160X

Figure 2
SEM Photomicrograph of Microballoon, 4A-6,
360X

ORIGINAL PAGE
COLOR PHOTOGRAPH

Figure 3

SEM Photomicrograph of Black Tile to Show the Fused Appearance, 2C. 160X

Figure 4
SEM Photomicrograph of Black Tile Surface to Show the Spherical Appearance of Fused Tile. 1246, 220X

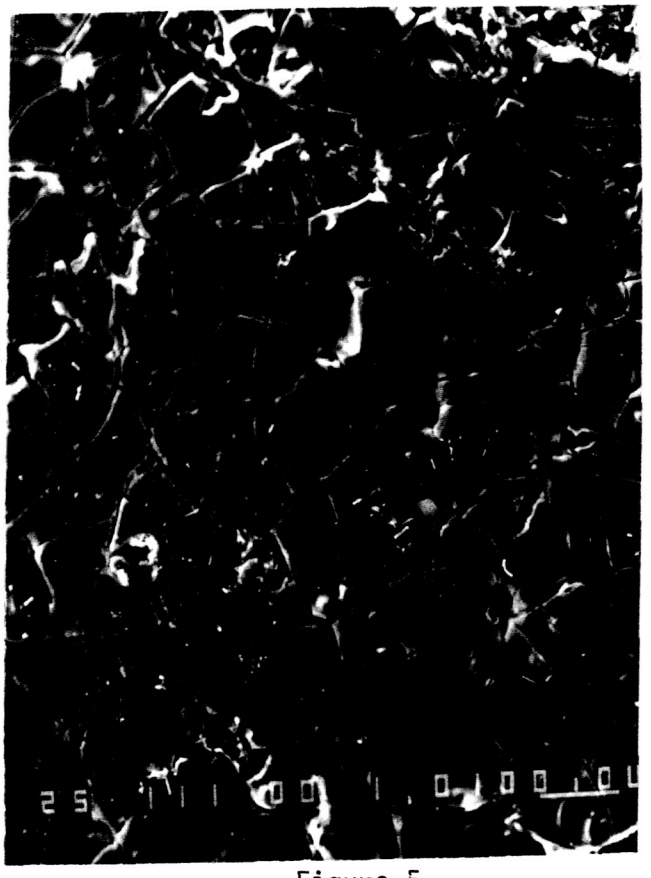


Figure 5
SEM Photomicrograph of the White Clear Materials on the Black Tile Surface. 1246. 110X. Mud-crack

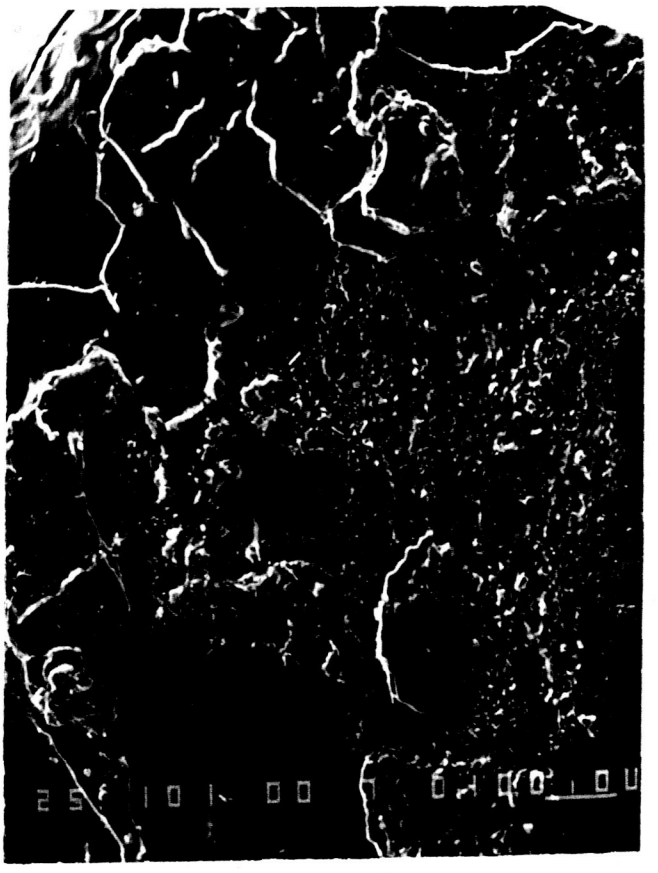


Figure 6
SEM Photomicrograph of the White Haze Deposits on the Black Tile Surface. 0279. 100X

Figure 7
SEM Photomicrograph of the Crusty Grey Materials. 0279. 300X

ORIGINAL PAGE
COLOR PHOTOGRAPH

MICROCHEMICAL ANALYSIS BRANCH
DM-MSL-1,ROOM 1274,0&C BUILDING
NASA/KSC
April 25, 1989

SUBJECT: Analysis of Wire from OV-103

LABORATORY REQUEST NO: MCB 257-89

RELATED DOCUMENTATION: Post-flight debris assessment

1.0 FOREWORD:

1.1 REQUESTER: Charles Stevenson/TV-MSD-22

1.2 REQUESTER'S SAMPLE DESCRIPTION:

Thin wire approximately 12 inches in length removed from the LH wing of OV-103 after landing

1.3 REQUESTED:

Determine the composition of the wire and any residuals on the surface

2.0 CHEMICAL ANALYSIS AND RESULTS:

2.1 The wire was approximately 1.5 mm in diameter.

2.2 The sample was analyzed by scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS) methods.

2.3 When magnified the wire appeared to be a rolled tube with a metallic aggregate core.

2.4 The "tube" material was carbon steel. Areas on the tube surface which resembled corrosion were found to contain a variety of materials, including: major Fe, minor/trace Ca and Si, and traces Mg, Al, P, S, Cl, K, Mn, and Zn. Another surface area showed major Fe, minor/trace S and traces P, Si, and Al.

2.5 The inner core was found to be a mixture of different types of materials. An overview showed major Fe, Ca, and Sr, minor Al, trace Mg, Ba, and Mn. Particles analyzed contained:

(1) Major Ca and Sr, trace Fe, Ba, and Al

(2) Major Mg and Al, minor/trace Fe, and trace Ca

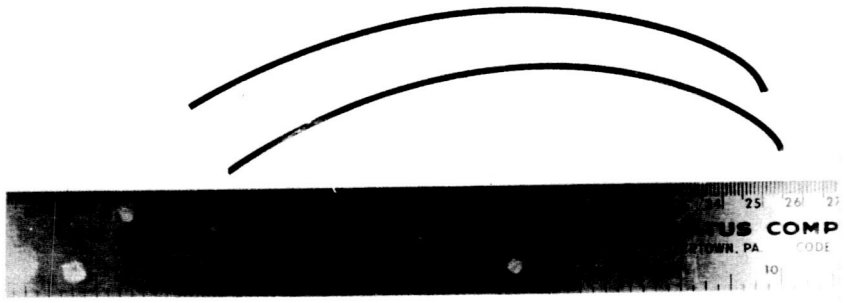
Other particles were a mixture of the same materials.

3.0 CONCLUSION:

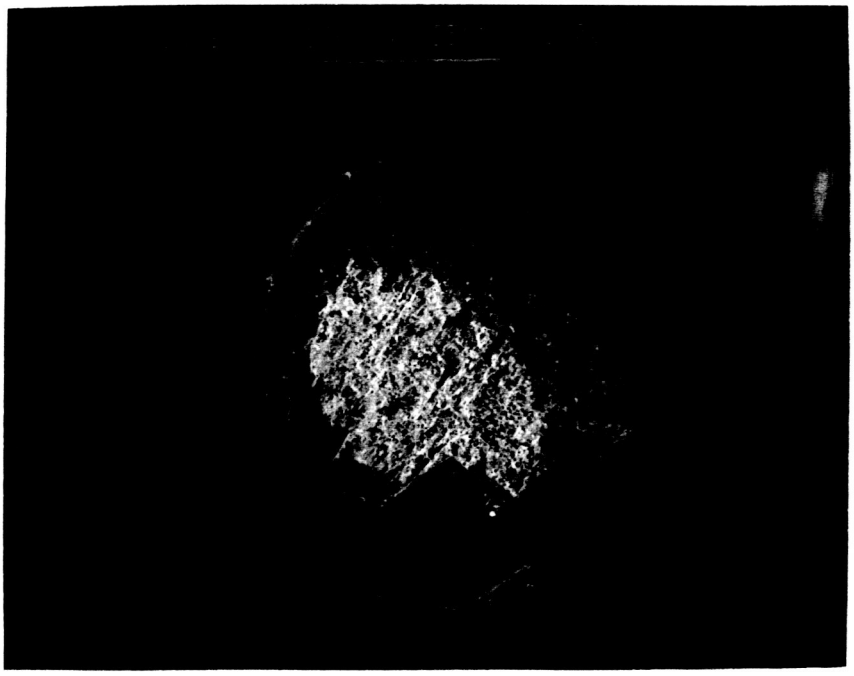
The wire is probably a carbon steel flux cored welding electrode, origin unknown. Core materials found are consistent with the types of materials used in flux cored electrodes with the exception of Sr (strontium), which was not listed in the welding references checked. However, flux materials are proprietary substances and Sr could be included as an undisclosed element.

CHEMIST: Kelly A Gorman
K. A. Gorman

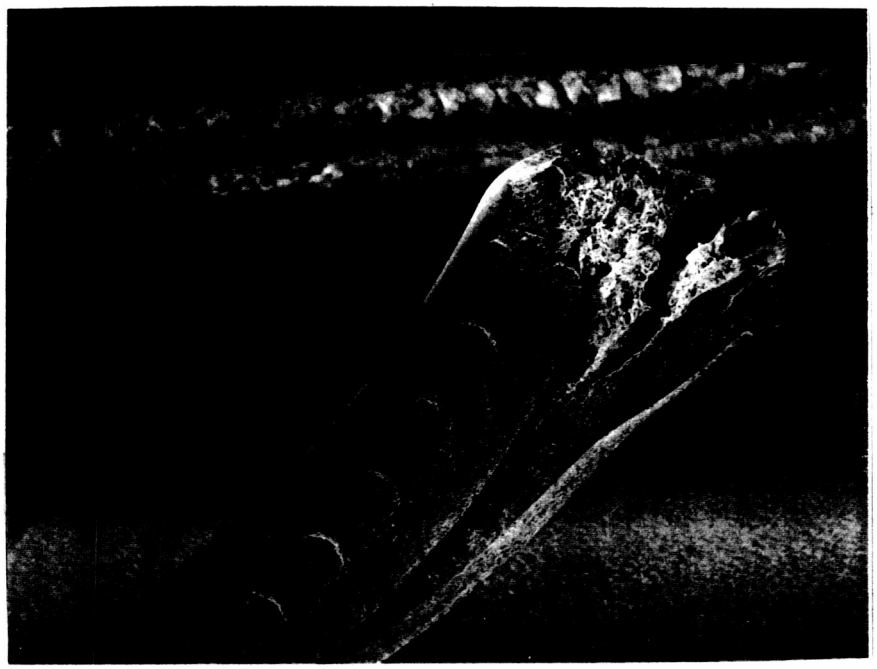
APPROVED: J. H. Jones
J. H. Jones

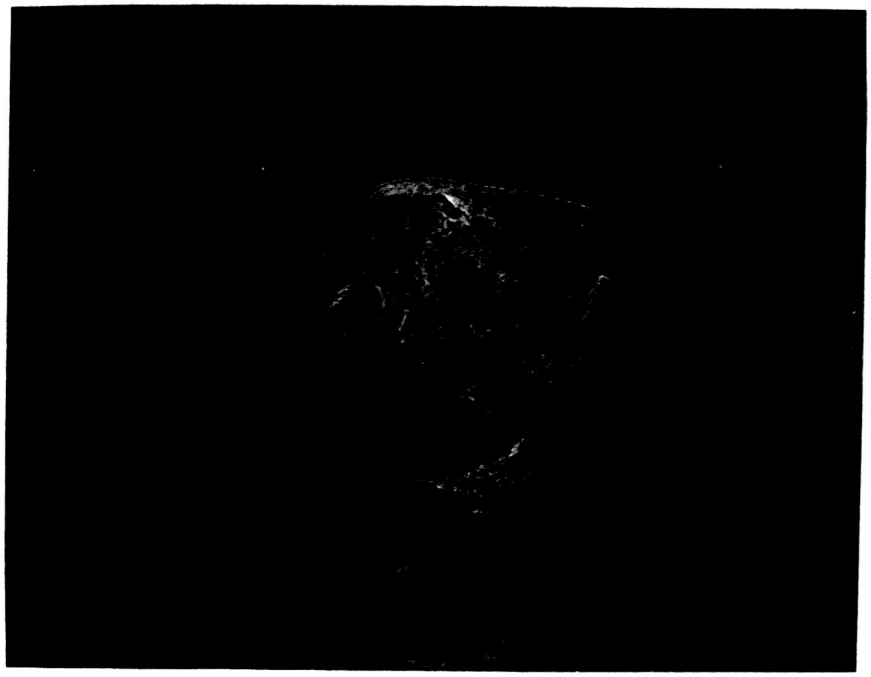


Overall photograph of two wires submitted for analysis



Cut wire end showing carbon steel shell and flux core





Wire, showing split end and flux core.

C-3

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Report Documentation Page

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15. Supplementary Notes

16. Abstract

An Ice/Frost/Debris assessment was conducted for Space Shuttle Mission STS-29R. Debris inspections of the flight elements and launch pad are performed before and after launch. Ice/Frost conditions on the External Tank are assessed by the use of computer programs, nomongraphs, and infrared scanner data during cryogenic loading of the vehicle followed by an on-pad visual inspection. High speed photography is analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage. This report documents the Ice/Frost/Debris conditions of Mission STS-29R and their effect on the Space Shuttle Program.

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